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NATURAL HISTORY OBJECT LESSONS

NATURAL HISTORY OBJECT LESSONS

A Manual for Teachers

[redacted]

By GEORGE RICKS B.Sc. (Lond.)
INSPECTOR OF SCHOOLS—SCHOOL BOARD FOR LONDON

Part I.—PLANTS AND THEIR PRODUCTS
ANIMALS AND THEIR USES
Part II.—SPECIMEN LESSONS

BOSTON, U.S.A.
D. C. HEATH & CO., PUBLISHERS
1893

[redacted]
June 11, 1932
[redacted]

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PREFACE.

In "Object Lessons, and How to Give Them," First and Second Series, we confined ourselves almost exclusively to the *Inorganic* World. In this volume, we propose to turn our attention to the *Organic* World. Plants and animals present an inexhaustible supply of subjects for "Object Lessons;" but the majority of teachers lack the time and opportunity to search out, gather, and arrange the suitable materials from so vast a treasury.

The object of this book is two-fold: (I.) To supply information from which the teacher, with the least effort, may prepare systematic courses of interesting and instructive "Natural History Lessons," suitable for Public Elementary Schools. (II.) To provide a sufficient number of specimen lessons (*a*) for the use of young teachers, and (*b*) to serve as guides in the preparation and construction of other lessons.

But in addition to this, a very general sketch of the Vegetable and Animal Kingdoms is given; sufficient to show to the teacher, not previously conversant with the subject, the general relations of the various groups of plants and animals to each other and to the whole, without which the more advanced lessons, at least, would lose much of their point and force.

The book must not be considered, however, in any sense a text-book either of Botany, or Zoology. For a more systematic review of plants the teacher is referred to a little book,* admirable as it is simple, written by V. Murche; and for a more comprehensive survey of the various groups of animals to the strikingly interesting series of "Natural History Readers" by J. G. Wood, M.A.†

* "Botany as a 'Specific' Subject." Blackie & Son. † London: Isbisters.

Properly presented, no lessons are so interesting and attractive to children as those which deal with living plants and animals; and none are more effective in the cultivation of habits of exact observation, accurate comparison, and sound reasoning. Some little trouble and forethought on the part of the teacher are necessary in the selection and preparation of materials.

In the case of plants, wherever possible, complete specimens, viz. with roots, stems, leaves, and flowers, should be brought before the class. Hence, in arranging the course of lessons regard must be had to the season of the year when particular plants can be obtained. There is often, too, an appropriateness in fitting the lesson to the season. A lesson on leaf-buds is most appropriate in spring; a lesson on the wheat-plant, or on fruits, is more suitable for the autumn.

As with plants, so with animals, wherever possible, take the living specimen in preference to the picture. It is of course not easy to bring many living animals into the school-room; but some at least may be introduced, and these will serve as types with which other and similar, but less familiar, animals may be compared.

Advantage should be taken of any pet animals which the children may happen to possess, such as white mice, rabbits, squirrel, hedgehog, &c. Besides these it will not be difficult to secure living specimens of birds, fish, frogs, and toads, the common ringed-snakes, insects, earthworms, snails, and so on. Some of these will serve to teach the children that many animals, commonly looked upon as unpleasant, unwholesome, or dangerous, on closer acquaintance prove to be harmless, interesting, and useful. Stuffed specimens of less familiar animals may be used with great advantage.

Of course the teacher will endeavour in his mode of dealing with living animals, as well as by precept in his lessons, to cultivate in his scholars a spirit of gentleness and kindly feeling towards all God's creatures weaker and more helpless than themselves.

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PART I.

PLANTS AND THEIR PRODUCTS; ANIMALS AND THEIR USES.

PLANTS AND THEIR PRODUCTS.

Section I.—Plants.

CHAPTER I.

INTRODUCTION.

THE earth is clothed with vegetation. From the burning sands and sweltering, humid valleys of the tropics to the confines of the eternal snows, plants, seemingly interminable in number and variety, luxuriate. Each country, each changing degree of temperature, has its particular plants. "The dynasty of the palms," says Linnæus, "reigns in the warm regions of the globe; the tropical zones are inhabited by whole races of trees and shrubs; a rich crown of plants adorns the plains of southern Europe; troops of green grasses occupy Holland and Denmark; numerous tribes of mosses are settled in Sweden; while the white and grey lichens alone vegetate in cold and frozen Lapland."

We may even recognise a country by the predominance of certain forms of vegetation. Forests of firs and pines transport us at once to northern latitudes, or to the flanks of high mountain ranges; forests of gum-trees and acacia tell us of Australia; the heaths point to South Africa; and the cactus to Mexico.

Not only do plants cover the earth, but they invade the sea; and, in prodigious numbers, draw their sustenance from the watery element which surrounds them. The "Gulf-weed" forms floating meadows in the ocean. "Midway in

the Atlantic is the great Sargasso* Sea, covering an area equal in extent to the Mississippi valley; it is so thickly matted with the Gulf-weed that the speed of vessels passing through it is often retarded. When the companions of Columbus saw it, they thought it marked the limits of navigation, and became alarmed. To the eye, at a little distance, it seems substantial enough to walk upon."†

Not only has each country and each sea its particular vegetation, but each tribe of plants requires its own peculiar conditions to bring it to perfection. Some revel in the scorching sunshine, others—like the red snow plant—flourish only on the frozen snow; some luxuriate in moisture, others prefer the parching drought; sunshine is the life of some, to others it brings death and decay; to some salt is necessary, and they find a habitation near the sea, on others salt acts as a destroyer; some prefer to flaunt their broad leaves on the surface of the water, others, more retiring, seek the sheltered nooks beneath.

Some plants lack the power of adapting themselves to slight changes in these conditions, and hence must always be restricted to certain localities: thus the cocoanut-palm grows only in lowlands near the sea; some on the other hand—like the potato—are more accommodating, and adapt themselves to a great variety of circumstances.

Plants make the earth beautiful; but they also serve a more useful purpose. We could not live without plants—they serve, directly or indirectly, as food for every living animal. Their special work is to change inorganic into organic matter.‡ They only are endowed with the inscrutable power of transforming air and water and earth into living matter, and of working them up into an infinite variety of beautiful and useful forms.

* Sargassum is the botanical name for the different species of Gulf-weed.

† Maury, "Physical Geography of the Sea."

‡ Matter organized or arranged to perform special functions.

Leaves of every form, flowers of every hue, the gnarled trunk, the fleshy root, hard nuts, succulent fruits, the sugar of the orange, the acid of the lemon, the starch of the potato, the oil of the olive, poisonous juices and refreshing beverages, are all elaborated from *sap;* and this sap is made from water, the carbonic acid gas of the air, and a little earthy matter.

And, in the very act of making vegetable matter, plants fulfil another great purpose of their existence, viz., they remove from the air a noxious gas, which, if left to accumulate, would be detrimental to the health of animals. The air we breathe is a mixture of two gases, oxygen and nitrogen, with some aqueous vapour, and traces of carbonic acid gas. Oxygen, which makes up about one-fifth of the air, is the supporter of life—we could not live without it. Now, as we breathe, we change a little of this oxygen into carbonic acid gas. The change takes place within the body, in every part, by the union of the oxygen carried by the blood with carbon from waste tissues. Now this gas is unfit for the breathing of animals—so much so that if it existed in quantity in the air they would be suffocated. But it is the chief food of plants. They constantly take it from the air, decompose it in their leaves; and, retaining the carbon, return the oxygen pure, to form the breath of life for animals once more.

CHAPTER II.

A TYPICAL PLANT.

All the common plants of our gardens, and fields, and hedgerows, consist of roots, stems, and leaves. At certain seasons these plants produce flowers, which in their turn yield fruits and seeds. The roots, stems, and leaves, being more imme-

diately concerned in the growth or vegetation of the plant, are called *organs of vegetation.* The flowers take no share in nourishing the plant; their special work is to prepare the seeds from which new plants will grow. They provide for the growth of new individuals of the same species; in other words, they *reproduce* and perpetuate the species. Hence flowers are called *organs of reproduction.*

I. The Organs of Vegetation.

1. The ROOT is the part of the plant which descends into the ground, sending its branches in all directions through the soil for the purpose of finding food for the plant. Real roots have neither pith nor true bark, and they never bear leaves.

2. The STEM is the ascending portion which bears the leaves and flowers. The leaves appear at intervals either singly, or in pairs, or in clusters, or whorls.

3. The LEAVES usually consist of a flat expanded portion which we call the *blade,* and the *leaf-stalk.* Leaves take in the larger portion of the plant's food from the air, and *digest* both this and that absorbed by the roots.

II. The Organs of Reproduction.

A flower, with all its parts present, consists of *two flower cups.* The outside one, usually green, is called the CALYX; the inner, usually coloured, is called the COROLLA; and within these cups are the STAMENS and PISTILS.

The flower cups serve for the protection of the stamens and pistils when in the bud. They are sometimes called, by virtue of their office, the *floral envelopes.*

The stamens and pistils are the *essential organs* of the flower, because both are *essential* to the formation of seed. The *stamens* consist of a number of thread-like stalks, each bearing a *sac* called the ANTHER. The Anthers are filled with a powdery-looking matter called POLLEN.

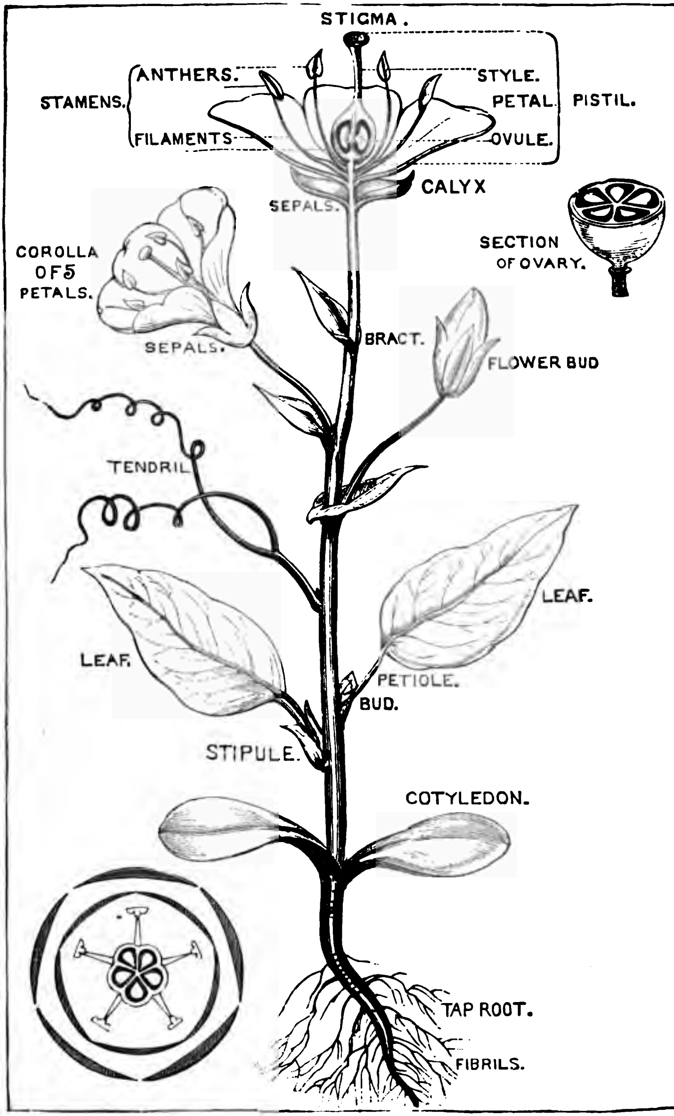


Fig. 2.—Section of Flower. Fig. 1.—A Typical Plant.

The *pistil* forms the centre of the flower. It consists of three parts, the OVARY, or seed vessel at the bottom, containing the ovules or young seeds; the STYLE, or stalk; and a rounded or flattened head called the STIGMA.

These are all the parts which any flower has; but many flowers have not all these parts. Some have a single instead of a double floral envelope, others possess neither; some stamens have no slender stalk, and some pistils have no style. The necessary parts—the *anthers*, the *ovary*, and *stigma*—are always present, though not in every case on the same plant.

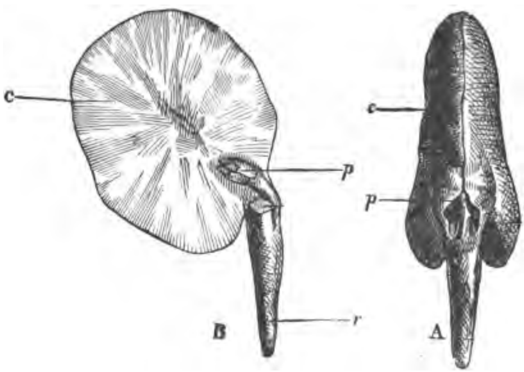


Fig. 3.—The Bean. *r*, radicle; *c*, cotyledon; *p*, plumule.

The FRUIT is really the ripened ovary, and the ripened ovules are called SEEDS.

The seeds consist of a *kernel* and its *shell.* Place a pea in water, and soon its softened shell or skin can be easily removed.

The kernel is a miniature plant, living, but sleeping till called into active growth by warmth and moisture. Botanists call the miniature plant in the seed the *germ*, or *embryo.* The kernel of the seed may consist of an embryo only, as in the bean or pea; or it may consist of an *embryo* with a store of

albumen outside, as in the seed of wheat. The white mealy mass, which we call flour, is the albumen of the cereals.

In all seeds the embryo consists of three parts, the *radicle*, *plumule*, and *cotyledons*. The radicle is the tiny *stemlet* from which the root grows, the plumule is the young *bud*, and the cotyledons are *seed-leaves*. Some seeds have one seed-leaf, others have two, and a few possess more than two. The cotyledons of the bean are large, fleshy lobes, full of albumen. The albumen stored up in the seed, whether outside the embryo, or in the seed-leaves, serves as food for the young plant.

CHAPTER III.

GENERAL CLASSIFICATION OF PLANTS.

There are so many thousands of different kinds of plants scattered over the globe that it would be impossible for any individual person to study the special characters of each kind. Hence it becomes necessary to present them in orderly array, grouping together those which are most alike, and separating those which are most unlike.

A knowledge of the structure and properties of one plant in a group will give us an insight into the character of the other members of the group.

Nearly all plants produce flowers; but the most superficial observer must have noticed that some plants—such as ferns, mosses, and lichens, are *flowerless*. Here, then, we have the first natural subdivision of all plants into two sub-kingdoms—the FLOWERING PLANTS, and the FLOWERLESS PLANTS.

We saw in the last chapter that some seeds have two

seed-leaves or *cotyledons*, while others have only one seed-leaf or *cotyledon*. This difference in the embryo is accompanied by other differences in the full-grown plant, which together serve to divide the flowering plants into two great classes, the DICOTYLEDONOUS and MONOCOTYLEDONOUS plants. For instance, the *stem* of a Dicotyledonous* plant has a distinct *bark*, and the *wood* is arranged in concentric layers round the central *pith*. Each year a new layer of wood is formed on the surface of that formed in the previous year. The *leaves* of this great class have their veins arranged in a kind of network, and the parts of the *flowers* in *fives* or *fours*, or multiples of these numbers, and very rarely in threes.

The *stem* of a monocotyledonous plant has *no distinct bark* which can be peeled clean off the wood, and the wood is arranged in *threads* which are *mixed up* with the pith throughout the stem. The veins of the leaves run in a nearly *straight direction* from the leaf-stalk to the point, and are almost *parallel* to each other. The parts of the flower are arranged in *threes*, or a multiple of three—very rarely in twos or fours, and never in fives.

Thus the *class* of any flowering plant may be discovered from an examination of a seed, or a piece of its stem; and it may be from a single leaf, or blossom.

Many seeds are very minute, and it is not possible to examine their structure without the aid of a microscope; nor can we always find seeds in a growing state. The structure of the stem is a guide quite as certain, and much more obvious to the naked eye than the structure of the seed. Hence it is more common to name the two great classes of flowering plants after the method of growth in the stem. In the first class, as we have seen, the stem increases by the addition of woody fibre on the *outside* of the woody

* The pine-trees and plants like them, which have more than two seed-leaves, are included in this class.

fibre previously formed. Such plants are named EXOGENS, or *outward*-growers. In the second class the bundles of woody fibre are deposited towards the centre of the stem, and these push out those previously formed and thus increase the diameter. Such plants are named ENDOGENS, or *inward*-growers.

The DICOTYLEDONOUS, or EXOGENOUS class includes the vast majority of plants in all parts of the globe. Nearly all the common herbs and shrubs and trees of this and other temperate countries are Exogenous. The MONOCOTYLEDONOUS, or ENDOGENOUS plants are represented in this country by the Cereals and other Grasses, the Lilies, the Onion, and a few others.

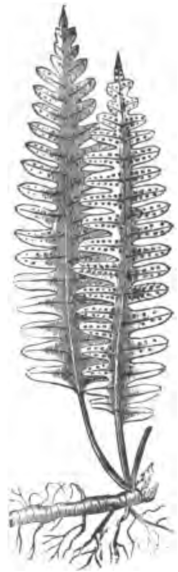


Fig. 4.—Fern-leaves, showing Spores.

The MONOCOTYLEDONOUS, or ENDOGENOUS, class are more characteristic of tropical regions, where they are found side by side with Exogenous plants. The Palms, Screw-pines, Bamboos, and Canes are the most striking examples.

The FLOWERLESS PLANTS bear no real flower with anthers and pistil, and so cannot produce real seeds. They produce, however, simple minute bodies, which answer the purpose of seeds. These are called *spores*. Spores may usually be seen in plenty on the under surface of the leaves of the Fern-tribe.

Ferns, Mosses, Lichens, Fungi, and Sea-weeds are all Flowerless plants reproduced by spores. These plants are usually arranged in two divisions. The first includes the Ferns and Mosses, whose stems grow by the addition at the *summit*. Such plants are called ACROGENS, or *summit*-growers.

The Lichens, Fungi, and Sea-weeds have neither distinct stem nor leaves; they consist of expansions of simple sacs, or cells. They are named THALLOGENS.*

Fig. 5.—Thallogen (Iceland Lichen).

CHAPTER IV.

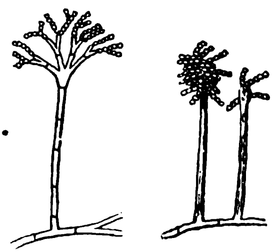
MINUTE STRUCTURE OF PLANTS.

Plants in their most simple forms are built up of vast numbers of microscopic *bags*, or *sacs*, or *bladders*, united together in various ways. These sacs are called *cells*, and the tissue formed by them is called CELLULAR TISSUE.

Cellular tissue plays the main part in the life-history of every plant which grows, and it is the chief fabric of which every plant is composed. The lowest tribes of plants, such as sea-weeds, lichens, mosses and mushrooms, consist of little else besides cellular tissue. In fact, they are often called *cellular plants.* The young plant, too, even of the

* *Thallos*, green shoot; and *genos*, birth.

highest tribes, consists entirely of this kind of structure; and in all newly-forming parts the foundation, as it were, is laid with cells. In the mature plant cellular tissue abounds in leaves, flowers, bark, pith, fleshy fruits, and succulent roots and stems.



Figs. 6 and 7.—Cellular Plants magnified.

If we take a young succulent leaf, and remove a piece of the delicate skin from the upper part of the leaf, we may see by the help of a pocket lens a vast number of green more or less rounded cells * closely packed together. This is the cellular tissue of the leaf.

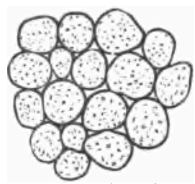


Fig. 8.—Cellular Tissue.

The cells which form cellular tissue vary very much in shape and size, and various changes take place in them during the growth of the plant. It will not be necessary for our present purpose, however, to consider all these. But there are certain cells, which are long and narrow and spindle-shaped from the first, to which we must refer. These serve a very important purpose. Each hair, for instance, of the "wool" which covers the seed of the cotton plant, is a single long cell. Flax, hemp, and jute are composed of similar *long* cells. All these cells when young have soft elastic walls, and their contents are semi-fluid, so that, in order that a soft young seedling may become a stout tree, the cells must become hardened

Fig. 9.—Cotton Seed and Hairs.

* For a closer examination of these cells a microscope is necessary.

in some way or other. This is effected by the deposit of a substance of a woody nature, formed from the half-fluid contents, on the inside of the cell-wall. In time, the walls become so thick that the cell is almost choked up. After this it undergoes no further change, and may be considered as practically dead. The hard shell of the cocoa-nut, the stone of the cherry, peach, and plum, and the "ivory" of the seed of the ivory-palm, are all formed from hardened *short* cells.

Tissue formed from the hard tough *long* cells is called WOODY TISSUE. The woody portion of trees, and shrubs and herbs, and indeed of all flowering plants, consists in part of this tissue. It exists also in the inner bark of trees, and in the veins of leaves. When separated from the more delicate tissues it forms the raw material for many textile manufactures, and is known under the general name of *bast*, or *liber*.

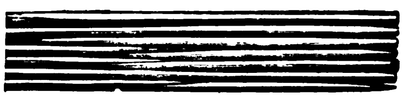


Fig. 10.—Woody Tissue, magnified.

Mixed up with the cellular and woody tissue, we find other tissue consisting of tubes. These appear to be formed from rows of cells, which have grown firmly together, and from which the partition walls have disappeared. Hollow tubes so formed are called vessels, and the tissue is named VASCULAR TISSUE. Sometimes these vessels contain a fine thread coiled round and round in a sort of spiral. This spiral fibre may easily be seen by making a superficial cut round the leaf-stalk of a strawberry or geranium, and then pulling the parts gently asunder. The uncoiled fibre looks like a spider's web.

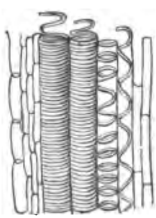


Fig. 11. — Spiral Vessels of Rhubarb.

All the parts of plants—roots, stems, leaves, flowers, fruits—are made up of cells and vessels of different kinds;

and by means of these simple tissues all the wondrous processes of vegetable life are carried on.

We may look upon the cells in their active state as nature's workshops—workshops invisible to the naked eye, silent, and mysterious; but yielding results, in variety and effect, such as the highest ingenuity of man could never have conceived. The staple produce of the cells in one plant may be starch, of those in another plant sugar; some plants yield medicines, others gums and resins; others again are perfume-factories, others colour-makers; but all the various products are made from the sap elaborated first by the leaves from the elements of water, and air, and a little earthy matter taken up from the soil.

CHAPTER V.

ROOTS AND THEIR FUNCTIONS.

Roots serve the double purpose of fixing the plant to the soil, and of absorbing the food and moisture necessary to its growth. It is the nature of the root to divide itself into branches and fibres, which spread beneath the ground. If we examine the sides and extremities of these underground branches, we shall find a number of delicate rootlets. The free ends of these rootlets are soft and spongy, and these are the parts by which the plants mainly absorb moisture. That roots absorb fluid very rapidly may readily be shown by taking a small growing plant, and, after cleansing of earth, immersing the roots in water. Of the water absorbed, however, but a small portion is retained by the plant,

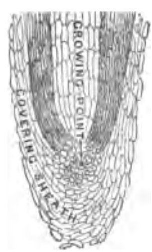


Fig. 12.—Tip of Root-fibre, magnified.

the greater part is sent out again by the leaves. This is probably owing to the fact that the solid mineral matters, which constitute an important part of the food of the plant, are dissolved in the water in very minute quantities, and to get a sufficient supply of these matters more water has to be absorbed than is necessary for the wants of the plant.


Fig. 13.—Tap Root of Turnip and Carrot.

Roots sometimes serve as winter storehouses for nourishing matter on which the plants feed in the ensuing year. Such are the *fleshy roots* of the turnip, carrot, parsnip, and raddish; and the *tuberous* root of the dahlia. Other roots supply only the present wants of the plant, that is, they absorb only. Such are the *fibrous roots* of trees, and bushes, and grasses.

There is a close connection between the kind of root, and the duration of life in a plant. *Trees* and *shrubs* all have branching roots, which finally end in tender fibres, or rootlets. These roots are needed mainly for absorbing nourishment from the soil. *Herbs*, viz., plants of soft texture, having little wood in their stems, and in our climate either dying down to the ground, or else perishing altogether in winter, have roots which vary in kind as the plant is an *annual*, *biennial*, or *perennial*. Annuals grow from the seed, blossom, ripen their seed, and die in the same season. Such plants have *fibrous* roots in clusters, or a main root branching into slender fibres. Biennials do not blossom the first season; they live over the winter, flower in the second year, and then die when they have ripened their seeds. In the

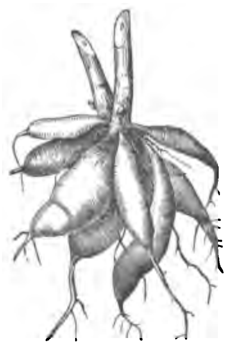


Fig. 14.—Dahlia Root.

first season these plants prepare a store of food, which is to be expended the next season in producing flowers and seeds. The plant-food is usually stored up in the root, as we have shown; but it is also sometimes found in the short stalk and leaves, as in the cabbage. Perennial herbs usually

Fig. 15.—Branching Root.

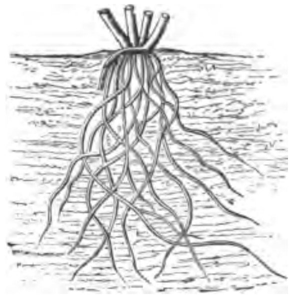


Fig. 16.—Fibrous Root. Buttercup.

die down to the ground as winter sets in; but some portion of the stem with buds, as, for instance, in the dahlia (Fig. 14), is kept alive underground till the following spring. In these cases a stock of nourishment is laid up in the roots, or elsewhere.

CHAPTER VI.

STEMS AND THEIR USES.

We may classify STEMS according to either their various *Forms*, or their *Internal Structure*.

The vast majority of plants have their stem *erect*. They elevate the leaves and flowers into the most favourable posision for receiving the influence of the light and air, on which their due actions depend. Other stems are *prostrate* or *trailing*, as that of the garden nasturtium; *creeping*, as in the strawberry-runners, or the *offsets* of the house-leek; *twining*,

as in the scarlet-runner, hop, honey-suckle, and convolvulus; or *climbing*, as that of the ivy, the pea, and grape-vine.

Twining plants rise by coiling themselves round any

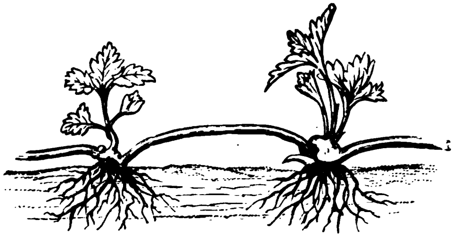


Fig. 17.—Strawberry.

Fig. 18.—House-leek.

object for support, and it is a curious fact that plants of the same kind always coil in one direction, while plants of

Fig. 19.—The Convolvulus.

Fig. 20.—The Hop.

another kind may coil in the opposite direction. Thus, the convolvulus stem coils from left to right,* and the stem of the hop from right to left.

* Namely, to a person supposed to be in the centre of the coil.

Climbing plants lift themselves up by means of *tendrils*, as in the pea and grape, or by tiny *rootlets* as in the ivy.

Fig. 21.—Sweet-pea, showing tendrils.

Fig. 22.—Ivy, showing rootlets.

In the Virginia creeper the end of each tendril spreads out into a little *disc*, which acts like a boy's sucker, and fixes

Fig. 23.—Virginia Creeper, suckers magnified.

the plant firmly to the wall. Some plants have their stems *underground.* Such stems send branches upwards at short

distances into the air. Mint, couch-grass, and Solomon's seal are good examples of underground stems.*

Fig. 24.—Couch-grass.

One of the most remarkable forms of the stem is that which presents itself in the potato. The potato plant has a portion of its stem underground, and this part sends out both roots and real branches (see Fig. 26).

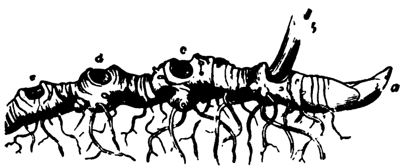


Fig. 25.—Root stock. Solomon's seal.

It is at the ends of these branches that potatoes are formed. If, when the stem of the potato plant is about a foot above ground, a portion of the stem is covered with earth, the covered portion will send out branches on which potatoes will be formed as well as roots. Every part of the potato-plant except the *tuber* dies off on the approach of winter; and the tuber is the special provision made by the plant for the reproduction of its kind next year. The eyes of the potato are real buds, and the solid flesh of the tuber

* For further information on kinds of stems see Murché's "Botany," page 18.

consists mainly of starch, the destined food of the young plant.

There are some other forms of stems commonly looked upon as roots, such as *bulbs* and *corms*. *Bulbs* are really *buds** covered with scales They grow underground, or partially so, as in the lily and onion. A *corm* is in form much like a bulb, only it is solid. It is a flattened underground stem. The crocus and snowdrop are familiar instances of the corm.

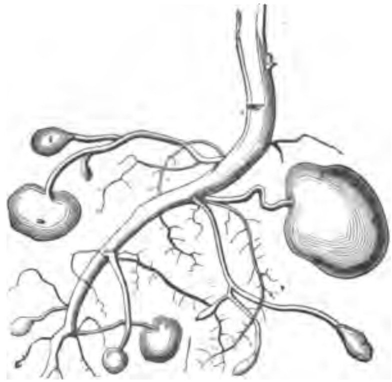


Fig. 26.—Potato.

We have seen that plants are composed for the most part of cellular tissue, woody tissue, and vascular tissue.

Fig. 27.—Bulb. Lily.

Fig. 28 —Corm. Crocus.

The cellular tissue makes up the soft parts of plants, the woody and vascular tissues form the harder fibrous parts. We have noted also (page 20) that the *arrangement* of these tissues in the stem is one of the distinguishing marks in the general classification of all plants into sub-

* For the nature of *buds* see p. 38.

kingdoms. In EXOGENOUS plants, whether herbs or shrubs or trees, the *woody bundles* are arranged round a central pith of cellular tissue, and the whole is enclosed by a layer of bark. In the first year there is no difference in the growth of the stem of the herb and the tree; but in the case of the latter a new layer of wood is formed in the second year outside the layer of the first year between it and the bark, and so on: year after year a new layer is formed. Hence it is that the number of layers in an exogenous stem tells the

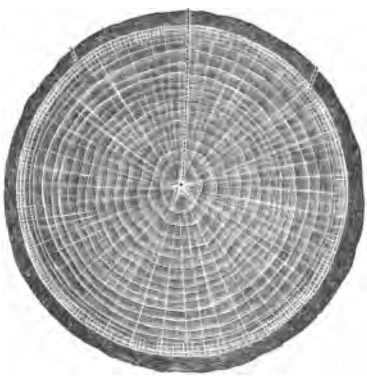


Fig. 29.—Section of Oak.

Fig. 30.—Section of Flax.

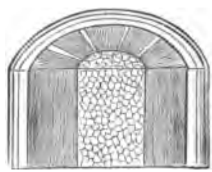


Fig. 31.—Section of one-year-old Oak.

age of the tree. It must not be supposed that the woody layers consist entirely of woody tissue; on the contrary, thin walls of cellular tissue extend irregularly from the pith to the bark. In a section of a stem these walls look like *rays*, radiating from the centre, and hence are called *medullary rays*. Cabinet-makers speak of these rays as the silver grain of the wood. Much of the beauty of polished oak depends on these medullary rays.

The *Bark* of Exogenous stems consists of two layers. The outer is formed of cellular tissue. In some plants, as in the

cork oak, this layer is very thick. The inner layer consists of woody tissue intermingled with loose cellular tissue. This layer forms a tough material, which, as we shall see later on, is much used in the manufacture of textile fabrics. Flax and hemp are the inner layers of the bark of the flax and hemp plants. But how and from what material are the layers of wood formed? If we strip off the bark from a branch, say of willow, in the spring of the year, we find between the bark and the wood a sticky semi-fluid. From this the cells are formed, soft and thin-walled at first, but gradually

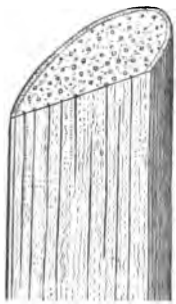


Fig. 32.—Section of Cane.

Fig. 33.—Section of Palm.

becoming hard and tough by the deposit of woody matter on their interior walls. The new wood thus formed is at first softer, and lighter in colour, than the older layers. It is known as *sap-wood,* while the first-formed layers form the *heart-wood.*

ENDOGENOUS stems consist of cellular tissue with the woody fibre arranged in bundles running lengthwise, and scattered throughout the whole thickness of the stems. A longitudinal section shows these fibres of wood to be long bundles; on the cross sections these ends appear like so many dots. The wood increases in amount as the stems grow older by the formation of new woody fibres among the old. Endogenous stems rarely branch; the asparagus stem is the

only common example in this country which branches freely. Most of the Endogenous stems are peculiar to hot countries, the palms being the most conspicuous examples. The commonest Endogenous plants of this country are the


Fig. 34.—Stem of Tree-fern.


Fig. 35.—Section of Stem of Tree-fern.

grasses (including the various kinds of grain), the asparagus, and the lilies.

The best example of the ACROGENOUS STEMS, or *summit growers*, are the tree-ferns. The tree-fern produces a crown of leaves at the summit, and it is the bases of these leaves, or fronds as they are called, which increase the length of the stem. The woody tissue is curiously arranged in a broken irregular circle near the outside of the stem.

CHAPTER VII.

LEAVES AND BUDS.

A complete LEAF consists of a *blade*, or expanded portion, a *petiole* or foot-stalk, and a pair of small leaf-like expansions—the *stipules*—at the base of the foot-stalk. Many leaves have no stipules, some have no foot-stalk; and in a few the petiole and blade are undistinguishable.

Leaves are either *simple* or *compound*. In a simple leaf

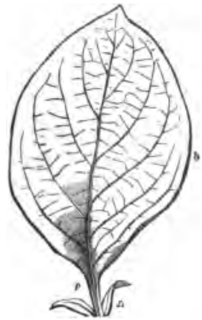


Fig. 36.—Simple Leaf, with Stipules.

Fig. 37.—Compound Leaf of Rose.

the blade consists of *one* piece; in a compound leaf the blade consists of *more than one* piece.

Like stems, leaves are made up of fibrous and vascular

Fig. 38.—Compound Leaf, Horse-chestnut.

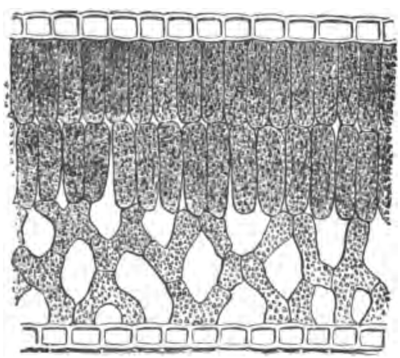


Fig. 39.—Transverse Section of Leaf.

(vessel) tissue, and cellular tissue. The ribs or veins which constitute the framework of the leaf consist of fibro-vascular

tissue, and the green pulpy portion which fills up the interstices, and is spread over the framework, consists of cellular tissue. The whole is protected by a thin, transparent skin called the *epidermis.*

The framework of the leaf is double. This may often be demonstrated in leaves which have lain in a damp ditch during the winter; the cellular substance has decayed, and so the cohesion between the upper and lower layers is destroyed, and the finger may be pushed between them.

The stouter pieces of this double framework are called *ribs,* the thinner pieces are called *veins.* Some leaves have one stout *mid-rib* running through the middle of the blade, from the petiole to the point, and from which veins branch off; other leaves have several ribs of nearly the same size spreading out from the petiole. Leaves of both these kinds are *net-veined,* or *reticulated,* because the veins branch off from the rib or ribs, and divide again and again, forming meshes of network throughout the leaf. Such leaves characterize Dicotyledonous plants, viz., those the seeds of which have a pair of seed-leaves, and the stems of which are exogenous.

Fig. 40.—Reticulate Leaf. The Mallow.

Some leaves, again, have ribs which run side by side without branching, or with very minute veinlets, from the footstalk to the point of the blade; such are *parallel-veined* leaves. These are characteristic of monocotyledonous plants, viz., those with one cotyledon attached to the embryo, and with endogenous stems. In some of the monocotyledonous

plants the veins run parallel from a mid-rib to the margin of the blade.

The surfaces of leaves are studded with openings communicating with air cavities within the substance of the leaves.

Fig. 41.—Parallel-veined Leaves.

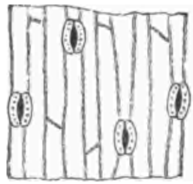


Fig. 42.—Stomata.

Fig. 43.—Vertical Section through a Stomate.

These are called *stomata*, or *stomates*, or *breathing pores*. They are surrounded by very delicate cells—usually kidney-shaped—which have the power of opening and closing the orifice. In dry weather the special cells collapse, and their sides touch each other; in moist weather they swell and lengthen and curve outwards in the middle, so as to leave an oval opening.

The stomata are most abundant on the under surface of leaves. Occasionally they are entirely absent from the upper side. They vary in number in different plants, from a few to many thousands to every square inch. Their office is evidently to regulate the passage of air and water to and from the leaf, hence they are seldom found in plants which grow under water.

Leaves exhibit an almost endless variety of forms in different plants. Botanists name them, for the purpose of

Fig. 44.—Bud of Horse-chestnut.

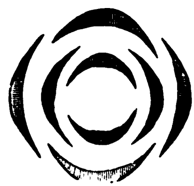


Fig. 45.—Section of Bud of Iris.

Fig. 46.—Section of Lilac Bud.

Fig. 47.—Section of Sage Bud.

correct description, according to (1) the general outline of the blade, (2) the point of the blade, (3) the margin, and (4) the lobing or division.

The BUD is the cradle of the young plant; it is, in fact, a rudimentary branch. In biennial and perennial plants buds are formed towards the close of the growing season (viz. in autumn) in the *axils* of the leaves. They are protected from the frost during winter, usually by a covering of scales.

In plants which grow in hot countries, and enjoy, so to speak, no annual repose, the buds have no special covering. The tiny leaves are wrapped up in the bud in various ways, but always in the same way in the same plant. [See Figs. 45—47.]

CHAPTER VIII.

FLOWERS—THEIR PARTS AND USES.

The *roots*, *stem*, and *leaves* are more especially organs for the growth and nourishment of the plant; the FLOWERS have for their special office the production of new plants; they are the *organs of reproduction.*

As already pointed out in Chapter II., these organs of reproduction consist of four parts, *calyx*, *corolla*, *stamens*, and

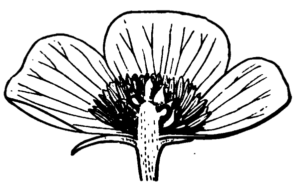


Fig. 48.—Section of Buttercup.

Fig. 49.—Incomplete Flower. Anemone.

pistil. The first two are *non-essential:* the stamens and pistil are *essential* organs. When all are present the flower is said to be a *complete* flower; when one or more of the parts are wanting the flower is said to be *incomplete.* Some flowers have a calyx, but no corolla; while in some the calyx only is absent. Some have stamens without a pistil, and others a pistil without stamens: but as these organs are both essential to the production of seed, when one flower has stamens or pistils only, another plant of the same kind will bear flowers

with pistils or stamens only. A few plants bear separate flowers of both kinds.

Flowers exhibit great variety in form, in colour, in arrangement on their stalks, in the relative position and number of the various parts, &c. For all these the reader is referred to the simple text-book already referred to. We shall content ourselves here with looking at the *general plan* of flowers.

Fig. 50.—Incomplete Flowers of White Willow in Catkins.

The calyx or outer covering consists of a number of leaf-like bodies called *sepals*; they are usually of a green colour. In some flowers the sepals are

Fig. 51.—Monosepalous Calyx.

Fig. 52.—Polysepalous Calyx.

Fig. 53.—Polypetalous Corolla.

combined, in others separate. The corolla or inner covering consists of *petals*, a whorl of leaf-like bodies; in some

flowers separate, in others more or less united, from the

Fig. 54.—Monopetalous Corolla.

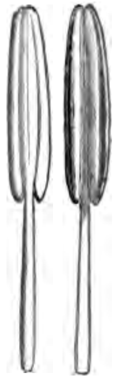


Fig. 55.—Stamens. Iris.

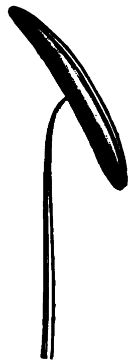


Fig 56.—Stamen. Amaryllis.

base upwards. The petals, which are generally coloured,

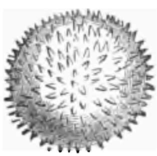


Fig. 57.—Pollen Grain. Hollyhock.

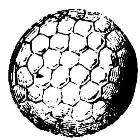


Fig. 58.—Pollen Grain. Phlox.

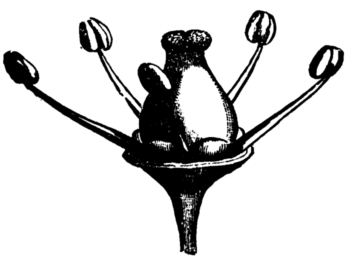


Fig. 59.—Stamens and Pistil.

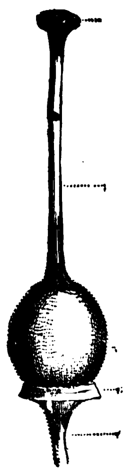


Fig. 60.—Pistil.

are arranged alternately with the sepals. The stamens

are arranged within the petals, and alternate with them. Each stamen has a sac, called the *anther*, which holds a powdery substance called *pollen*. The anther may be either sessile (without stalk), or supported on a stalk which is called the *filament*. The pistil is the central organ,

Fig. 61.—Pistil of Five Carpels.

Fig. 62.—Section of Ovary. Saxifrage.

Fig. 63.—Adherent Ovary of Fuchsia.

below and around which the stamens and floral envelopes are arranged; it consists of one or more parts, called *carpels* (fruits), either separate or combined. A simple pistil (one carpel) consists of a lower portion, the *ovary*, which includes the *ovules* destined to become seeds; and an upper part, the *stigma*, which is a portion of loose cellular tissue without any skin covering. The stigma may be sessile on the ovary, or elevated on a stalk called the *style*. In a compound pistil

the carpels may be either combined (grown together) or separate.

All the organs of the flower are situated at the end of the flower-stalk, and this part is called the *receptacle,* or *thalamus,* or *torus.* In some flowers the receptacle is considerably expanded for the attachment of the floral organs. The calyx and corolla are designed simply to protect the essential organs of the flower from the effects of rain, wind, or sun while they are young and tender. When the ovary has grown firm and strong, and moreover needs the warmth of the sun to ripen its seeds, the petals, and in most cases the sepals, die and fall off.

But before this happens a change has been brought about in the ovules, whereby they have been changed from ovules to *seeds.* The processes involved in this change we know, but how they are effected is a mystery.

The anther is essentially an oblong sac or box, divided longitudinally into two chambers—*lobes* as they are called. In these lobes the pollen grains are fully developed, and when ripened the anther itself bursts to let them out.

But, while the pollen grains are maturing, the surface of the stigma has also undergone a change. It has become rough, and sometimes hairy, and is covered with a slightly sticky fluid. As the pollen grains fall from the bursting anther they are caught upon the stigma, the rough, moist surface of which prevents them falling off.

Fig. 64.—Anther discharging Pollen.

Very often the pollen grains are carried to the stigma by bees and other insects, in their visits to the flowers for honey, especially when the staminate and pistillate flowers are on different plants, or on different parts of the same plant.

Under the microscope the pollen is seen to consist of minute simple cells. These cells vary very much in shape

and colour in different plants, but are always alike in the same plant. In every essential particular, however, they are the same. On the moist surface of the stigma they become

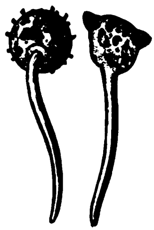


Fig. 65.—Pollen Grains with Tubes.

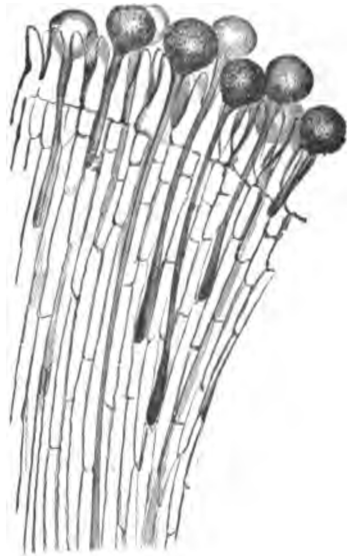


Fig. 66.—Tubes of Pollen Grains penetrating the Tissue of the Stigma.

active and grow. Each cell sends out a long slender tube, the *pollen-tube*, which slowly penetrates through the loose tissue of the stigma and through the style (when one is present) into the ovary. Into this pollen-tube the active vital fluid of the pollen-cell passes to the ovule, which thus becomes fertilised.

CHAPTER IX.

FRUITS AND SEEDS.

In the flower, as we have seen, the *ovary*, consisting of one or more *carpels*, contains the *ovules*. After fertilisation the

ovary is called the *seed-vessel*, and the ovules become *seeds* in name. But before the young seeds arrive at maturity many and important changes take place, especially in the parts which enclose and protect the seed. The receptacle, the calyx, as well as the carpels, play an important part in the production of " fruits " of various kinds. It should be noted that the walls of the carpels consist of three layers, the *endocarp*, the *mesocarp*, and the *epicarp*, that is, the inner, middle, and outside layers. These are not easily distinguished in the early stage, but are shown very distinctly in the ripe fruit. Thus in the plum or cherry the hard shell which immediately enc'oses the seed is the endocarp, the luscious pulp is the mesocarp, and the thin outer skin is the epicarp.

We may now examine more closely the formation of what are commonly called "fruits," "nuts," "berries," "pods," "seeds," &c.

Such fruits as are produced from a simple pistil, including pistils formed of a single carpel or of several *combined*, may be termed *simple fruits*. And these are formed from (1) the ovary and calyx grown together, or (2) the simple ovary. To the former belong the *fleshy fruits*, viz., the *berries*, the *gourds*, and the *pomes*; to the latter belong (*a*) *stone fruits*, such as the *cherry*, and (*b*) *dry fruits*, such as *grains* and *nuts*.

Fig. 67.—Section of Cucumber, showing the Seeds.

In *berries*, such as gooseberry, currant, cranberry, grape, &c., there is a soft, pulpy portion, which appears to be formed from the endocarp; the epicarp and calyx grown together form the skin. The fruit of the *gourd* tribe of plants—the cucumber, melon, vegetable marrow, &c.—is precisely the same kind of fruit as the berry, except that the rind is harder. The *pome*, including such fruits as the apple, pear, and hawthorn, is formed somewhat differently; it

comes from a compound pistil with a coherent calyx-tube. It is the calyx-tube which grows thick and fleshy, and makes the eatable part of the fruit. The real seed-vessels are five

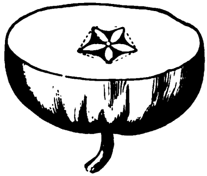


Fig. 68.—Horizontal Section of Apple.

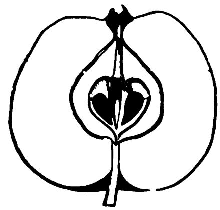


Fig. 69.—Vertical Section of Apple.

in number, enclosed with parchment-like walls. Immediately surrounding the seed-vessels, and inside a circle of greenish lines, is the flesh of the *core*. This is formed from the enlarged receptacle of the flower.

In the *stone fruits* or *drupes*, such as plums, cherries, peaches, apricots, and almonds, as has already been pointed out, the

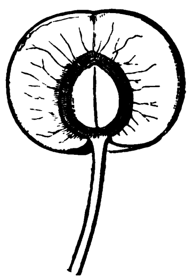


Fig. 70.—Section of Cherry.

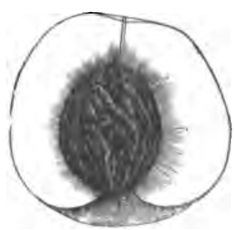


Fig. 71.—Section of Plum.

"stone" is formed from the endocarp, the flesh from the mesocarp, and the skin from the epicarp. In the almond the middle covering becomes tough and leathery instead of juicy and pulpy.

Dry fruits have no soft, fleshy layers; they are either *dehiscent* or *indehiscent*, that is, they may split open in some

regular way to discharge the seed, or they may remain closed till the seed begins to grow, or until the seed-vessel decays. (All fleshy and stone fruits are of course indehiscent.)

Of the *indehiscent* dry fruits the *achene*, the *grain*, and the *nut* are the most familiar examples. The *achene* includes all

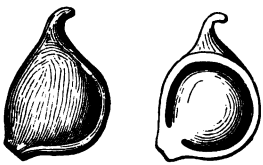


Fig. 72.—Achene of Buttercup.

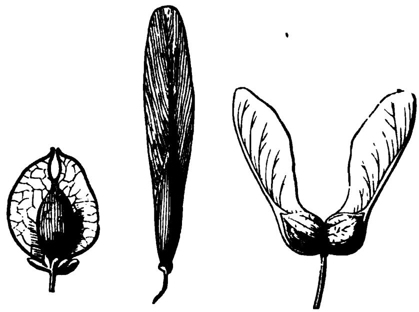


Fig. 73.—Key. Elm, Ash, Maple.

dry, one-seeded, closed, small fruits, many of which are often mistaken for naked seeds, such as the little seed-like fruits of the buttercup. The *grain* is the same as an achene, except that the seed-vessel adheres firmly to the seed. Wheat, barley, maize, rice, and oats are examples. The *nut* is an achene on a larger scale, and the seed-vessel becomes a hard shell; chestnuts, beechnuts, filberts, and acorns are examples. All these are enclosed, or partly enclosed, by an outer covering, which forms no part of the real fruit. Some achenes, as the fruit of the ash, elm, and maple, have a kind of winged appendage; these are called *key* fruits.

Dehiscent fruits are known under the names of *pods* and *capsules* ; *pods* result from pistils formed of single carpels; they usually split open lengthwise when ripe and dry. The pea family, the peony, and marsh-marigold are common examples. *Capsules* are formed from compound pistils;

they dehisce in various ways (see Figs. 74 to 79). One of the most interesting of the capsules is that of the poppy-

Fig. 74.—Pea-pod. Fig. 75.—Fruit of Tulip. Fig. 76.—Capsule bursting.

head (Fig. 79). On the summit we see the old stigma, which never falls off. When the fruit is ripe little cracks

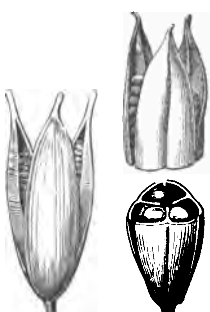


Fig. 77.—Capsules bursting. Fig. 78.—Capsule. Wall-flower. Fig. 79.—Capsule. Poppy.

form all round the under part of the stigma, through which the seeds may be shaken out like pepper from a box.

Other fruits less simple in their formation are called *aggregated*, *accessory*, and *multiple* fruits. To the first of these classes the blackberry and raspberry belong. Each single fruit is a collection of smaller fruits, each of which is a

Fig. 80.—Blackberry.

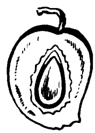


Fig. 81.—Section of Fruitlet of Blackberry.

Fig. 82.—Strawberry.

drupe, like a cherry or plum. The strawberry is the best example of an accessory fruit: all the soft, fleshy part is

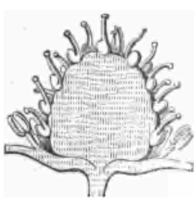


Fig. 83.—Section of Strawberry. Showing Pistils and Stamen.

Fig. 84.—Mulberry.

simply the receptacle grown large and juicy, so that the fruit is not a berry at all. Scattered over the surface of the fleshy receptacle are the real fruits—small dry achenes like

those of the buttercup. The mulberry and pine-apple are familiar examples of multiple fruits. The mulberry is a cluster of small fruits just like the blackberry, only that the mulberry is formed from a cluster of flowers, and the blackberry from the numerous pistils of a single flower. In the mulberry the juicy pulp is produced from the calyx of each flower, and not from the pistil, as in the blackberry. The real fruit is an achene, like that of the strawberry; it will be found embedded here and there in the pulpy flesh.

Section II.—Economic Products of Plants.

CHAPTER X.

THE PALM-TREES.

"FROM their noble aspect, and perhaps also from the surpassing usefulness of several members of the group, the PALMS have been looked upon as the princes of the vegetable world." It is impossible to over-estimate their utility to the inhabitants of the countries where they grow. Every part of the tree in its turn appears to be put to some profitable use. They furnish food, clothing, shelter, timber, fuel, building materials, weapons, paper, starch, sugar, oil, wax, wine, tannin, dyeing materials, resin, medicines, and a host of minor products.

The members of the tribe which furnish the most abundant economic products are the *date* palm, the *cocoa-nut* palm, the *oil* palm, and the *sago* palm. Besides these may be mentioned the *cabbage* palm of the West Indies, the terminal bud of which furnishes a delicious vegetable; the *areca*, or *betel-nut* palm of the East India Islands, the nuts of which are chewed as a narcotic; and the *gornuto* palm of Southern Asia, the great source of palm wine. South America is preeminently the land of palms. Here, in the vast virgin forests of Brazil, flourish hundreds of different species of palms yielding to the native Indians all they need in life for food, shelter, clothing, lights, and medicine.

THE DATE-PALM.—The date-palm is one of the most noble and, at the same time, one of the most useful of this

tribe of beautiful trees. Its praises have been sung in every age and clime. It is the chief source of the national wealth of the inhabitants of Arabia, and the borders of the great African desert, the fruit being the staple article of food. The tree rears its column-like stem to a height of sixty feet or more; and terminates in a crown of large, but graceful feathery leaves. Great flower stalks issue from horny sheaths, growing between the leaves and the stem, and bear small white flowers. The flowers are succeeded by the fruit, which hangs in great bunches several feet long. Dates vary in size, colour, and quality, as much as does the apple in our country; while the recognised and named varieties of one fruit are as numerous as those of the other.

The date harvest is looked forward to with as much anxiety as the vintage in France, or the corn harvest in England. Famine would follow a failure of the crop. The fresh fruit is eaten without any preparation. "Those who, like most Europeans at home," says a celebrated traveller in Arabia, "only know the date from the dried specimens of that fruit shown beneath a label in shop windows, can hardly imagine how delicious it is when eaten fresh, and in central Arabia. Nor is it, when gathered fresh, heating—a defect inherent to the preserved fruit everywhere—nor does its richness, however great, bring satiety; in short, it is an article of food alike pleasant and healthful." In the oases of the Sahara, and in other parts of northern Africa, dates are pounded and pressed into cakes, which serve as a supply of food till the new harvest arrives again. The date-palm furnishes almost everything that the Arab requires in life. It gives a grateful shade in a land where the rays of the sun are almost insupportable. Camels, as well as men, feed on the fruit. An incision in the trunk yields a sweet liquor, which by fermentation becomes wine. The timber of the trunk is used for building purposes and in the manufacture of furniture. The leaves are used as thatch, and the foot-

stalks as fuel; while, in addition, ropes and mats and many other articles are made from fibres obtained from the leaves. Date-sugar, a valuable commercial product of the East Indies, is obtained from the juice of a species of palm closely allied to the date-palm.

THE COCOA-NUT PALM.—The cocoa-nut palm is a beautiful and lofty tree. Its column-like stem shoots up to a height of from sixty to a hundred feet, and terminates in a crown of graceful, waving, pinnate leaves. These leaves often attain a length of twelve or fifteen feet, and with their strong mid-ribs and numerous long, acute leaflets resemble gigantic feathers. The flowers are arranged in clusters five or six feet long, and they are enclosed in a tough spathe. The fruit is enclosed in a thick fibrous *husk*. Inside this is the hard *shell*, which protects the *kernel*, and the *milk* within.

The cocoa-nut palm flourishes on the coasts of tropical countries: in the East and West Indies, on the shores of tropical America, on the shores of India and especially of Ceylon, and it finds a congenial home on all the warm islands in the broad Pacific. In Ceylon alone not less than twenty million trees are cultivated in plantations. "The first operation in cocoa-nut planting is the formation of a nursery, for which purpose ripe nuts are placed in squares containing about four hundred each. These are covered an inch deep with sand and sea-weed, or soft mud from the beach, and are watered daily until they germinate. Those put down in April are sufficiently grown to be planted out before the rains of September, and they are then set in holes three feet deep and thirty feet apart. They must be protected from the glare of the sun, and watered when necessary for the first two years. They begin to bear fruit in from five to seven years after planting, and the average produce of a fair-sized tree is sixty nuts yearly." *

* Sir J. Emerson Tennant, on Ceylon.

The uses to which the various parts of this tree are put are almost endless. It has been not unaptly called the "tree of a hundred uses." The nuts are used for food, and the milky fluid serves for drink. The juice of the unexpanded flower-spathe forms an agreeable drink under the name of "toddy" or palm wine. From "toddy," sugar can be obtained; and when fermented "arrack," a spirituous liquor, can be distilled over. The trunk yields the porcupine wood of commerce, and is made to serve every possible purpose from the manufacture of knife-handles to the construction of door-posts. The leaves are made into baskets, or used as thatch for the villagers' cottages; and the leaf-stalks serve for garden fences. The kernel yields the valuable cocoa-nut oil used in the manufacture of candles, and the fibrous husk is made into ropes, brushes, matting, &c.

For the preparation of the oil the kernels are first broken into small pieces and dried in the sun; one thousand full-sized nuts yield about five hundred pounds of these dried pieces, named *copiæ*, and these yield by pressure, or boiling, about twenty-five gallons of oil. At ordinary temperatures this oil is a white solid; under great pressure the more liquid oil is squeezed out, and hard *cocoa-stearin* for candle-making is left behind. Marine soap, which will form a lather with sea-water, is made from cocoa-nut oil. The value of the cocoa-nut oil imported every year from Ceylon and India alone amounts to upwards of £300,000.

THE OIL-PALM.—The oil-palm tree grows principally in the countries bordering the West coast of Africa, and palm-oil is the chief article of commerce of the West African ports. The fruit is borne on dense heads, sometimes two feet or more in length and two feet in circumference. The fruit itself is similar in size and shape to the olive; but is of a beautiful golden-yellow colour. The seeds are enclosed in a hard shell, and the shell is covered with a fleshy fibrous rind. It is from this rind that the best oil is obtained. The

fruit, when ripe, is boiled in earthenware pans and then crushed. The crushed mass is then placed in large shallow clay vats nearly filled with water, and women tread out the oil, which comes to the surface. The oil is collected, boiled to get rid of the water, and then packed in barrels for export. Good palm-oil possesses a bright orange colour; and, when it arrives in this country, has the consistency of butter. In Africa it is used for food; in England it is bleached and manufactured into candles and soap. It is also used for greasing the axles of railway carriages. The annual import of palm-oil from the west coast of Africa exceeds £1,000,000 in value.

CHAPTER XI.

GRASSES—THE CEREALS, THE SUGAR-CANE, THE BAMBOO.

The general appearance of the ordinary grasses is familiar to us all. The long narrow leaves, and the hollow-jointed and cylindrical stalks, serve to distinguish them from all other plants. To the grass tribe belong not only the numerous and varied grasses of our meadows and hillsides, but also all those grains, such as *Wheat, Rice, Maize, Barley, Oats, Rye,* and *Millet,* which are used as food for man and beast, together with the juicy *Sugar-cane* and the tall *Bamboo.*

The grasses are very widely distributed, being found in every quarter of the globe; and they constitute by far the most important group of plants in the vegetable kingdom.

WHEAT is the most extensively grown, and the most important of all the cereals. It is largely cultivated in the United States, in Canada, in most European countries,

especially in France and Russia; in India, in Australia, and in many other countries.

There are many varieties of wheat, following chiefly from the differences in the conditions of soil and climate under which the plant is cultivated. The chief are *hard* wheats and *soft* wheats, which are sown in the autumn; and the *spring* wheat sown in the early months of the year. Spring wheat, like barley, is bearded. The grain of hard wheat is harder and drier, and keeps better than that of the other kinds; but soft wheat yields the whitest flour, and sells at a higher rate. Hungarian flour is generally considered the best in this country.

As an article of food wheat is more largely consumed than either maize, rice, oats, barley, or millet,—although some of the latter contain a larger percentage of nutriment, and are far cheaper,—and probably for this reason, *wheaten flour alone is well adapted to make fermented bread.*

The chief sources of supply of wheat and wheaten flour for Great Britain, taken in order, are the United States, Russia, Germany, and Australia.

RICE is believed to be a plant native to India: certainly it has been cultivated there from the very earliest times. Naturally a marsh plant, rice requires a damp soil, and moist, hot atmosphere to bring it to perfection. Hence it is cultivated in the low plains and great river valleys of tropical and sub-tropical countries, which are either periodically flooded, or which admit of easy and copious irrigation.

The method of cultivation varies in different countries. In the States it is sown in trenches in spring, and the ground is then flooded for several days. When the young plants are a few inches high a second flooding is given, and again when the harvest time is approaching the flooding is repeated. In some countries the seeds are scattered as the floods are subsiding, and the grains sink into the mud and speedily germinate. In Lower Bengal, in July of each year, hundreds

of square miles of rice-fields may be seen covered with water from the overflow of the Ganges, the ears of grain floating on the surface of the water.

The finest rice is grown in the rich swampy lands of North and South Carolina. The Patna rice of Bengal ranks next in quality. The chief rice-growing districts in the world are China, India—especially in the valleys of the Ganges, Irawadi, and Brahmaputra—and the United States of America. Much of the rice is imported in the husk as a protection against injury in transit. In this state it is called *paddy*.

"Rice is second only to wheat as an article of human diet, and forms the chief nutriment of at least one-third of the inhabitants of the globe. It is admirably adapted to the wants of the inhabitants of the tropics as it is not so heating to the human system as any other cereal, and it is a specific for diarrhœa and dysentery, which are so prevalent in those climates."

India and Burmah are the chief sources whence we draw our supplies of rice.

MAIZE, or Indian-corn, is a plant of the new world.* It is most extensively cultivated in the United States and Mexico. There are many varieties of maize which differ among themselves as much as they differ from the other cereals. They vary in height,—from ten inches to ten feet; in time of coming to maturity—from two to seven months; in shape and size of ears, and in the colour of the grain—which may be white, yellow, purple or even striped. It requires a warm climate and a rich soil to bring it to perfection. Its cultivation is simple, and the returns very large, its produce being greater than that of any other grain.

As an article of food Indian-corn flour is very extensively used. It is not well adapted for making bread; but is

* It is probably a native of Mexico.

sometimes mixed with wheaten-flour for that purpose. The grain contains a larger proportion of oil than any other corn, and is therefore possessed of remarkable fattening properties. Deprived of its gluten it becomes *corn-flour.** One kind of "sweet" maize is grown in the States for boiling in its green state as a culinary vegetable like green-peas.

Not less than 18,000,000 bushels of maize are grown in the States annually, of which about 200,000 are used in the manufacture of starch.

BARLEY, OATS, RYE.—These cereals are much hardier than wheat or maize, and hence they flourish in colder climates. *Barley* is cultivated extensively in Russia, Roumania, Germany and Denmark, and in our own country; oats in Russia, Sweden and Scotland; and rye in Russia, Germany and Holland. Barley is used mainly for making malt for brewing beer, and distilling spirits. Barley-meal, or barley-flour, is used as a fattening food for pigs and other animals. Pearl-barley is made by grinding off the husks in mills adapted for that purpose. *Oats* form an exceedingly wholesome and nutritious article of food. The kiln-dried grain, from which the husks have been removed, ground into coarse meal, is known as *oat-meal.* The people of Scotland eat oat-meal extensively in the form of *porridge.* The greatest consumption of oats, however, is as food for horses. Rye-meal is largely used among the poorer classes in Russia for making *rye-bread*—a bread which is dark in colour, coarse, heavy and unpalatable. *Millet* is grown in India, Egypt, Italy, Spain, and in Asia Minor, and Arabia. One species is known under the name of Dhurra. In many Eastern countries millet is used for food; in this country it is used for feeding poultry.

The BAMBOO is the giant of the grass tribe; but in every respect it is a grass. The stem is hollow like that of most

* See chapter on Starch, page 62.

other grasses, and it forms at intervals the same joint or knot. The flower also is enclosed in a couple of bracts or scales, which serve the place of petals just as in common grass. It grows almost everywhere in the tropics. China seems to be its natural home; but it is abundant in India and the East India Islands, and it forms dense jungles in the valleys of the Andes. There are many species of bamboo; the most common has a slender hollow knotted stem 40, 60, or even 80 feet long, having any thickness up to 18 or 20 inches. The stems grow very fast, extending to its entire length in a few months. Many columns rise from the same root, and from the higher joints; and when the stem has reached its full length there springs a set of smaller branches or shoots. These shoots are also jointed and another series of smaller shoots spring from these again, and so on, until the last shoot is nothing more than a narrow pointed leaf. As each bamboo in the thicket sends out shoots in like manner, a thick almost impenetrable mass of feathery-looking foliage is formed.

The bamboo is one of the most useful plants that nature has given for the use of man. The soft vigorous shoots are eaten like asparagus, or they are salted and eaten with rice, or candied and eaten as a preserve. The seeds are sometimes eaten, especially when rice is scarce.

It is the stem, however, which is the more abundantly useful part of the bamboo. In China, India, and Japan it is made to serve purposes almost innumerable. The Chinaman builds his house of bamboo, and furnishes it, even to bedsteads and bedding, with the same material. With the outer part of the stem the Chinese and Japanese manufacture wicker work unequalled for beauty and neatness of workmanship, and the inner parts are beaten into pulp for making the finest paper. The bamboo is also used for making the sails, cables, and rigging of the junks that stud the rivers and canals, for the manufacture of implements of husbandry, for

building bridges, for constructing water-pipes, and even for making buckets and bottles.

The SUGAR-CANE is another of the very valuable members of the grass tribe. The cane is a stem of grass jointed as in all other grasses; but it grows to a height of 12 feet or more, and measures 4 or 5 inches round. It is propagated mainly by cuttings, and the canes attain their full growth in from twelve to fifteen months. The stalks are surmounted by pale lilac flower-heads from 1 to 2 feet in length, so that a field of canes in full bloom is a pretty sight. Unlike our meadow grasses and the various cereals, the stalks are solid, being filled with pith. This pith, when the plant is in a mature condition, contains about 90 per cent. of juice. It is from this juice that sugar is obtained.

When ripe the canes are cut down, and at once carted to the crushing mill, where they are crushed and squeezed between large iron rollers. The expressed juice is a solution in water of from 12 to 20 per cent. of sugar, with traces of other substances, albumen, gum, a peculiar substance resembling gluten, and the usual mineral ingredients.

The process of separating the sugar from the juice is somewhat complicated, but the principle is very simple; a little quicklime is added, and the juice is passed at once from the vessels in which collected to evaporating-pans or large copper boilers where it is boiled. The boiling causes the albumen and gluten to coagulate, just as the white of eggs coagulate on boiling; and this rises to the top as a thick scum and carries most of the impurities with it. The scum is removed, and the juice is now passed on to other vessels, where it undergoes similar processes of boiling and skimming. As the water is gradually driven off as steam the juice thickens, and when it becomes about as thick as oil, the syrup is poured into shallow pans and allowed to cool. As it cools the sugar separates from the liquid in small crystals, and the former is drained off. The crystals

we call *raw sugar*, and the liquid drained off *molasses*, or *treacle*.

It takes from 12 to 14 tons of good ripe canes to yield 1,500 gallons of juice, from which about a hogshead of sugar is obtained. Much of the sugar is left in the canes, and some is lost during the boiling, so that in practice less than one-half of the sugar contained in the canes is secured.

When the canes have been cut, others spring up in their places; but the plants require to be renewed every six or seven years. The canes diminish in size and length every year; but yield a richer juice.

The sugar-cane is cultivated in most tropical countries where there is sufficient moisture. It is grown most extensively in the West and East India Islands, in the United States, in the Mauritius and in Brazil, and from these countries we draw our chief supplies of sugar. The total yearly import of sugar into Great Britain is about *twenty million* cwt., valued at about *twenty million* pounds.

Sugar is also manufactured from the juice of several other plants, the chief of which are the beet-root, sugar-maple, palm-trees, and sugar-millet. The sugar obtained from all these plants are called "cane-sugars." * Beet-root sugar is manufactured in Germany, France, Austria, and Russia, to the extent of 1¼ million tons yearly. Sugar is extracted from the sap of the sugar-maple, but mainly for home consumption in the United States [Northern]. In the West Indies, India, and Ceylon, sugar is made from the juice of the flower-buds of palm-trees, and in China from the sugar-millet.

* To distinguish them from the grape-sugar—a sugar obtained from grapes and other fruit, much less soluble in water than cane sugars.

CHAPTER XII.

STARCHES.

Starch exists in all plants. It is stored up in the *cells* for the purpose of nutrition, and is met with in great abundance in the seeds of the corn-tribe, in peas and beans, in the tubers of potatoes, in the tuberous rhizome of the arrow-root plants, in the pith of the sago-palm, and in the juice of the carrot, beet, &c.

The starch generally assumes a granular form. The granules are transparent, and too small to be seen by the naked eye. Under the microscope they present a variety of shapes and sizes according to the plants whence they are derived. Indeed it is quite possible to determine the source of the starch by the form and size of the starch granules. The starch grains are really little bags or sacs, which contain the true starchy matter. When put into hot water these sacs swell out and burst, and the contents are set free. This is why starch once dissolved can never be restored to its original form.

Starch as sold in the shops for laundry purposes is either a white glistening powder, or it is in form of columnar masses easily reducible to powder. When pressed between the fingers starch gives a harsh feeling, and emits a peculiar crackling sound. It is heavier than water, and is insoluble in cold water, and in spirits of wine. Mixed with hot water it assumes the well-known viscous pasty condition, in which form it is used to stiffen linen. Mixed with cold water, or cold milk, and baked or boiled, it becomes converted into consistent puddings.

The principal kinds of starch used as *food* are arrow-root, tapioca, tous-les-mois, sago, and corn-flour.

Arrow-root is the starch obtained from two or three species of arrow-root plants [Maranta]. These plants are

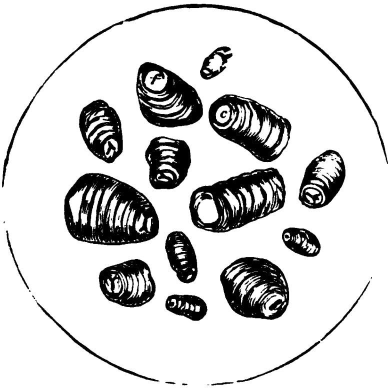


Fig. 85.- Rice Starch.

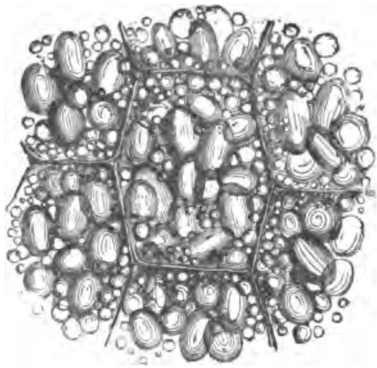


Fig. 86.—Wheat Starch.

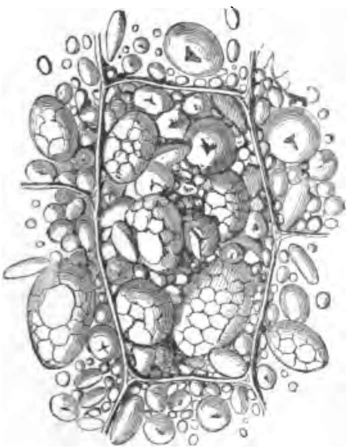


Fig. 87.—Maize Starch.

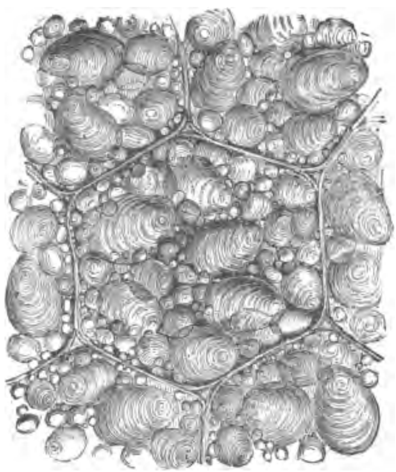


Fig. 88.—Potato Starch.

native to the American continent; but are extensively cultivated in most tropical countries. The best arrow-root is obtained from the West India Islands, St. Vincent being now the chief seat of the arrow-root culture. The arrow-root plant produces a scaly, white, tuberous rhizome; and it is from this part of the plant that the starch is prepared. The rhizomes are gorged with starch grains, especially just before the period of rest; and if collected at this time yield 25 per cent. of starch. They are carefully peeled before grating, because the skin of the rhizome contains a resin which would colour and give a disagreeable flavour to the arrow-root.

TOUS-LES-MOIS, another kind of arrow-root, is obtained from the various species of Canna, a plant allied to the Maranta.

Brazillian arrow-root is the starch obtained from the Cassava, or Manioc plant. When agglutinated into fine globules on hot plates, it forms the TAPIOCA of commerce.

British arrow-root is prepared from potato starch.

SAGO is obtained from the soft cellular interior of the stem of the sago-palm. When the tree is full grown,* it is cut down, and the fat gummy-looking substance is extracted from the trunk. This is reduced to powder, mixed with pure water, and strained through fine cloth to separate the glutinous and woody matter. The starch, when separated from the water and partially dried, is passed through sieves to give it the well-known granular appearance of the sago of commerce. Almost all the sago imported into this country, about 300,000 lbs. a year, is brought from Singapore. Sago forms a wholesome and nutritious food; but it is also used as a starch for textile fabrics.

CORN-FLOUR is obtained from maize, or Indian corn. The grains are steeped in water; and, when swollen, are crushed under water between cylinders. The mass is then passed

* The tree is then about 30 feet high and 20 inches in diameter.

into sieves, when the milky-looking fluid holding the starch passes through, and the husky matter is retained. The former is conducted into *settling* tanks, where the starch gradually settles at the bottom. The liquid is next drawn off, and the deposit is purified by repeated washing and settling, and then separated from the water and dried at a gentle heat.

The chief sources of starch for *industrial purposes* are potatoes, wheat, and rice.

POTATO STARCH.—The manufacture of starch from potatoes is an important industry in Germany, Holland, Russia, and America; and, during the time when the potato disease was very prevalent, large quantities were made in this country. It is a curious fact that diseased potatoes yield as pure and useful a starch as the sound tubers.

In order to extract the starch the potatoes are well cleansed, and then rasped by machinery. The pulp is received on a sieve, and is washed continuously by a gentle stream of water so long as the washings are milky-looking. The milkiness is caused by the granules of starch held in suspension. The liquid is conducted into *settling vats*; and, as in the case of corn-flour, the starch which settles is repeatedly washed, separated from the water, and dried at a gentle heat. Potatoes contain about 20 per cent. of starch and 76 per cent. of water.

WHEAT STARCH.—RICE STARCH.—In England starch is made chiefly from wheat and rice. The manufacture may be illustrated on a small scale by putting a small quantity of flour in a muslin bag, and working it with the fingers under water. The starch passes into the water and gradually settles at the bottom of the vessel. Considerably more than the half of wheat and rice consists of starch; but these cereals contain also another substance called *gluten* in considerable quantities (12 to 20 per cent.).

Formerly this *gluten* was wasted in the manufacture of

starch; but of late years the practice has been to separate the *gluten* and *starch* by steeping first the grain and then the flour-paste in a very dilute solution of caustic soda. The fibrous matter of the grain is easily got rid of by stirring the mixture with water. The fibres quickly subside to the bottom, when the milky fluid containing the starch is run off into separate vessels, where the starch is deposited and the liquor drawn off. (The latter contains the gluten, which is separated by adding sufficient sulphuric acid to neutralize the soda. The gluten is used for feeding cattle.)

After cleansing, a little blue colour is added to the starch, which on gently drying assumes the well-known columnar structure.

Violet powder is scented starch.

Starch baked at a moderate heat in an oven is soluble in water, and forms with it a kind of gum called *Dextrin*, or *British Gum*.

Dextrin is used as a substitute for the more expensive Gum Arabic for a great variety of purposes. It is used for sizing paper, for stiffening cotton goods, for thickening colours used in calico printing, and also in the preparation of lozenges, labels, adhesive stamps, and surgical bandages.

CHAPTER XIII.

OILS AND FATS (VEGETABLE).

Every species of plant produces an oil in more or less abundance possessing some characteristic property peculiar to itself. One property, however, distinguishes all oils. They are readily inflammable; and, on burning, leave no solid residue.*

Water boils at 212° Fahr. and becomes steam; and the

* Being composed almost entirely of hydrogen and carbon (occasionally oxygen is present), they produce by their full and free combustion in oxygen, water and carbonic acid gas only.

steam may be cooled into water again. Oils boil and become vapour at different temperatures, usually much higher than water. Thus oil obtained from orange peel boils at 345° Fahr., and oil of cloves boils at 480° Fahr. Now many of the oils cannot be heated to their boiling point under ordinary circumstances: they decompose into other substances and give off offensive vapours. In other words, under ordinary conditions we cannot change them to vapour of oil, and hence cannot distil them. Such oils are called *fixed* oils. Those oils which can be vaporized without decomposition are called *volatile* oils. Olive-oil, palm-oil, linseed-oil, and cocoa-nut oil are examples of *fixed* oils. Oil of cloves, oil of mint, oil of turpentine, and oil of lemon are examples of *volatile* oils.

To determine whether an oil is fixed or volatile, let a drop fall on a piece of clean blotting paper and heat the paper until it is slightly charred. If the oil disappears leaving no stain behind, it is all volatile: if a greasy spot remains, it is wholly or partially fixed.

FIXED OILS.—Vegetable fixed oils are nearly all fluid at ordinary temperatures in this country; but a few, which are liquid in the country of their production, are solid here: such are palm-oil, cocoa-nut oil, and Chinese tallow. Solid oils are sometimes termed *fats*. The fats and oils are all lighter than water, and all soluble in ether, oil of turpentine, and benzin. Hence these solvents are used to take grease spots out of cloth, &c. They render paper semi-transparent, producing what is well known as a greasy stain.

The vegetable fats and oils occur in various parts of the plant; but they are most abundant in the fruit and seed. Olive-oil and palm-oil are obtained from the fleshy fruit. The oils of linseed, hemp-seed, rape-seed, cotton-seed, are, as their names imply, all expressed from seeds; and so likewise are castor-oil, and poppy-oil. Cocoa-nut oil, and nut oils of various kinds, are obtained from kernels.

Oils are extracted from nuts and seeds by simple pressure, by pressure after heating, and occasionally by the action of solvents. The oil obtained by pressure is called *cold drawn*, or *virgin oil.*

Heating the crushed kernels or seeds renders the oil more fluid, and consequently it presses out more easily, but the oil is not so pure. The heat should never exceed 175° Fahr.

When the oil is extracted by a solvent, a heavy colourless fluid called bisulphide of carbon is used. The bruised seeds are digested in the liquid, which dissolves the oil. The mixture is then distilled, when the bisulphide distils off in vapour at a temperature of 115° Fahr. Steam blown through the oil destroys all trace of the sulphur.

The refining of oil is a separate industry. Several methods are employed. Perhaps the most simple is to add 2 or 3 per cent. of caustic soda to the heated oil. The soda forms soap with a small portion of the oil, which, rising to the top as scum, carries all impurities with it.

Some fixed oils dry and become hard on exposure to the atmosphere, others do not dry. Hence we may divide the fixed oils into *drying* and *non-drying.* The various uses to which these oils are applied in the arts and industries depend on their drying or non-drying properties. Drying oils would be useless for lubricating machinery, and non-drying would be worthless for mixing paint and varnishes. The chief of the drying oils are linseed, poppy, hemp, and sunflower; and the most important of the non-drying are palm-oil,* olive-oil, rape-oil, colza-oil, and castor-oil.

LINSEED-OIL.—Linseed-oil is obtained from the seeds of the flax plant, which yield about one-fifth of their weight of oil. This oil is of a light yellow colour, and possesses a slight peculiar odour. Owing to its powerful drying properties, which are much increased after heating with a little red lead or black oxide of manganese, it is extensively used

* For palm-oil see Oil-Palm Tree, page 54.

in the preparation of paint. If heated for some time it is converted into a dark tenacious mass, which may be drawn out into threads. This, properly mixed with ground charcoal, constitutes *printer's ink.* Flax-seed, or linseed, is obtained principally from the East Indies and Russia, whence upwards of *four million pounds' worth* are imported every year.

The oils obtained from the POPPY, HEMP, SUNFLOWER, and COTTON are used for purposes similar to linseed-oil; but cotton-seed oil and sunflower-oil are not good drying oils. Sunflower-oil, which is produced in vast quantities in Russia, India, and China, and more recently in Germany and Italy, is almost equal to olive-oil for table use. It makes soap of a superior quality, and the seeds are also used for fattening poultry.

RAPE and COLZA oils are obtained from the seeds of plants of the cabbage family. They are used chiefly for lighting purposes.

OLIVE-OIL.—The olive-tree grows wild in the countries bordering the Mediterranean sea; and the very name seems to suggest the idea of Palestine, and the sunny lands of the East. The fruit of the wild olive is not of much value. It is the fruit of the cultivated trees of Italy, Spain, and the South of France, which yields the valuable article of commerce known as olive-oil. The common olive is an evergreen of from 20 to 30 feet in height; but the cultivated trees are kept much lower by constant pruning.

The fruit resembles damsons in size and shape, the fleshy part outside the stone being hard and thick. Unripe, the colour is yellowish blue or green, but changes to dark purple, or black, as the fruit ripens. The oil is obtained by pressure from the ripe fruit. That which is expressed from hand-picked fruit under light pressure is the most esteemed. It is called *virgin oil.* The common olive-oil is obtained by stronger pressure, or with the aid of heat, or after the olives (having been collected into heaps) have remained till a kind

of fermentation has set in. A still inferior quality is obtained from the residue by boiling in water. This is used in the manufacture of soap.

In many parts of Spain and Greece, and generally in Asia Minor, the ancient* custom of *beating* or *shaking* the tree to obtain the ripe fruit is still followed, with the result that the oil is of inferior quality.

The olive-tree has in all ages been held in the highest estimation. It is frequently mentioned in the Bible, and the oil is associated with the corn and wine and milk and honey—the treasures of the Promised Land. Olive wreaths were used by the Greeks and Romans to crown the brows of victors; and the tree is still universally regarded as the emblem of peace and harmony.

Olive-oil is an insipid, inodorous, pale greenish-yellow coloured fluid, very inflammable, and not liable to turn rancid. It is the lightest of all fixed oils, and becomes solid at a temperature considerably above the freezing point of water. To a limited extent it is used in the preparation of food in this country; but it may be regarded as the cream and butter of Italy and Spain.

The unripe fruit of the olive-tree is pickled, and used as a dessert.

Olive-oil is imported (almost exclusively from Italy, Spain, Turkey, and Greece) to the annual value of about *one million* pounds.

CASTOR-OIL is a well-known viscous fluid. Where pure it has but a slight odour, and is almost colourless; but it possesses a very nauseous and disagreeable taste: it is obtained from the seeds of the castor-oil plant. This plant grows to a height of about five or six feet in England; but in the West Indies it often reaches a height of twenty feet in one season. The seeds are about the size of horse-beans: when ripe they

* "When thou *beatest* thine olive-tree, thou shalt not go over the boughs again; it shall be for the stranger, for the fatherless, and the widow."

are shelled and crushed between rollers, and the crushed mass is put in hempen cloths, and pressed in a screw or hydraulic press. The oil which exudes is placed in water and heated to nearly boiling, when the gummy matter rises to the top as scum. The oil is then strained and bleached in sunlight, and is known as *cold-drawn castor-oil.* In India it is obtained in such abundance as to be used for illuminating, as well as for domestic and medicinal purposes; and it is from India that we draw our main supply.

VOLATILE OILS are more or less aromatic, the scent being that of the plant from which the oil is derived. Formerly these oils were regarded as the subtle essence of the plant, and hence were called "essential oils." They are obtained chiefly from the leaves and flowers by distillation, and other methods; but some are also extracted from the seed. The oils of orange and lemon are got by simple pressure from the rind.

The volatile oils are mostly limpid liquids, lighter than water: they have an aromatic smell, and hot, burning taste: they dissolve freely in ether, alcohol, and mineral oils: they burn freely, with a smoky flame, are not greasy to the touch, and do not give a permanent grease-spot: they have high boiling points; but in the presence of water or steam they readily distil over at a lower temperature.

The volatile oils are used chiefly in medicine and perfumery. Among the most common are *oil of turpentine,* the most valuable of all; the *oil of bergamot,* obtained from the rind of the ripe fruit of the lime; *oil of carraway,* from carraway-seed; *oil of cloves,* from the unexpanded flower-buds of the clove-tree; *oil of lemon, oil of nutmeg,* &c.

OIL-CAKE, viz., the refuse cake from which oil has been extracted, contains a considerable portion of oil, the whole of the albuminous matter, sugar, gum, and starch of the seed. This forms in *most cases* a highly concentrated nutritious food for fattening cattle. The cakes from castor, mustard,

and croton seeds are unsuitable, because of the active principle contained in the oil. Linseed and rape-seed cake are the best.

CHAPTER XIV.

GUMS, RESINS, GUM-RESINS, GUTTA-PERCHA, INDIA-RUBBER.

GUM exists in the juices of nearly all plants, and is present in such abundance in several as to flow in plenty from the bark, when wounded, or when its surface cracks. The gummy exudations may occasionally be seen on the cherry and plum-trees of our own country. It is produced in its purest form by the various species of the acacia tribe. The name *gum* is applied only to those exudations which are entirely soluble in water, or which soften in water and form a thick glutinous liquid; but which are not soluble in spirits of wine.

GUM ARABIC when pure is transparent and colourless; the commoner kinds have a yellow tinge. It has a glassy lustre and insipid taste, and is entirely soluble in water. It is imported into this country in large quantities on account of its extensive use in the textile manufacture, and in calico-printing. Gum arabic is obtained chiefly from Egypt and Austria.

Like gum arabic, *gum Senegal* is obtained from a species of acacia, but is of inferior quality; *gum tragacanth*, or *gum dragon*, is obtained from the stem of a prickly plant growing in Asia Minor, and is shipped from Smyrna. This gum is employed in some kinds of calico-printing.

The common gum, used for labels, postage-stamps, envelopes, &c., is made by baking starch at a moderate heat till it assumes a pale brown colour, and is soluble in water. A portion of sugar is added to enable the cement to be more readily softened on the application of moisture.

RESINS are solid inflammable substances which, like gums, are obtained from the stems and branches of trees; but, unlike gums, are insoluble in water, and soluble in alcohol and the essential oils. They are more or less brittle, transparent, or translucent, and of a colour inclining to yellow.

They are generally obtained by making incisions into the wood of trees which produce them, when they exude in the form of a thick liquid of about the consistency of honey. These liquids consist of resin dissolved in the essential oil of the plant, and to obtain the resin the essential oil is distilled off. Common turpentine consists of resin dissolved in oil of turpentine. When distilled with water the oil comes over with the steam; and the residue, amounting to from 75 to 90 per cent. of the turpentine employed, is the common *resin* of commerce. The common turpentine is obtained from pine-trees; and the pine-trees of the North American forests supply the world. Common resin is extensively used in the manufacture of soap; and in the preparation of plasters and ointments. The oil of turpentine is used for diluting oil-colours, so that they will flow freely from the painter's brush.

Venice turpentine—a clear, transparent liquid—is obtained from the silver fir.

Copal, lac, and *mastic* are resins obtained from tropical trees; they are chiefly used in the preparation of fine varnishes for pictures and maps.

Balsams are resins mixed with essential oil. Balsam of Canada is the nearly colourless liquid resin of a species of pine.

Gum-resins are mixtures of resins, essential oils, and gums; they are much used in medicines, and many of them are valued for their fragrance. Frankincense, myrrh, and gamboge are gum-resins.

GUTTA-PERCHA * is the solidified juice of a tall tree which

* From Malayan *gutta* = gum, and *percha*, the name of the tree; hence gum of the percha-tree.

grows in the Malay peninsula and in the adjacent islands. The wood is soft, fibrous, and spongy, and useless as timber. Immediately after the rainy season the trees are cut down ten or twelve feet from the ground; and the branches are lopped off to prevent the gutta from ascending to the leaves. Small pieces of the bark are now removed, and the milky juice or gutta runs out, and is collected. The juice rapidly hardens on exposure to the air. Usually it is boiled in iron pans, to get rid of water, before it is allowed to become solid. A large tree will sometimes yield from 30 to 60 lbs. of juice, but 30 per cent. of the weight is lost in drying.

For manufacturing purposes the imported gutta-percha has to be purified. For this purpose it is heated by steam till quite soft, then torn to shreds and placed in water, when the impurities sink to the bottom. The gutta is now heated again, and kneaded and rolled, or pressed into blocks. During the last process certain substances, such as red-lead, sulphur, and resin are added, either for colouring purposes or to increase the hardness.

As prepared, gutta-percha is tough, strong, hard, and flexible. It is a trifle lighter than water, and possesses a peculiar odour. It softens on being heated, and becomes elastic. In this state it can be moulded to any form, becoming rigid again as it cools. It is highly inflammable, and burns with a bright white flame and much smoke, at the same time dropping a black residue which looks like sealing-wax. It is insoluble in water, spirits of wine, and dilute acids; but soluble in warm turpentine, and in cold naphtha. It is impervious to water, even in thin sheets, and a non-conductor of electricity.

Gutta-percha is used for a great variety of purposes—for soles of boots and shoes, for water-pipes, speaking-tubes, waterproof sheeting, picture-frames, cups, inkstands, &c., and for covering telegraph-wires. In the year 1883, 58,706

cwt., of the value of £425,813, were imported from the Straits Settlements.

INDIA-RUBBER is the dried coagulated milky juice of various trees and shrubs. It exists in the sap of the network of lactiferous vessels of the middle layer of the bark. The best rubber is obtained by the careful evaporation of the recently strained juice at a moderate heat.

The trees from which india-rubber is obtained grow freely in the tropics. The chief sources of supply are South America, Central America, the West Indies, Mozambique, West Africa, and the East Indies. The forests of the Amazon yield the best rubber, and immense cargoes are shipped every year from Pará, a town on the banks of this river.

Various methods are adopted to coagulate the juice, dependent to a great extent on the species of plant from which the sap has been taken, such as the addition of alum, or hot water, or sea-water, or the juice of other plants; but the juice of the siphonia, the Amazonian india-rubber tree, needs nothing but a gentle heat.

The process of collecting and preparing in the Amazon forests is somewhat as follows:—

The india-rubber maker, on finding sufficient trees tolerably close together to be worth working, has first to make his "india-rubber path" through the trackless forest, that is, a path from tree to tree to the number he wants, generally about a hundred; then he has to clear away the moss and creepers from the trunks so as to leave a clear space for "tapping." The trees are "tapped" with a small axe, slant cuts are made not quite through the bark, at about every eight inches of circumference, and under the incisions small tin, or other vessels, are fixed by means of clay. Tapping goes on with the week. On Monday the workman taps as high as he can reach, on Tuesday a foot or so lower, and on Saturday pretty nearly on the ground. The lower the

tapping, the greater the yield; that on Saturday is often nearly double that of Monday. The vessels having previously been placed at the foot of each tree, the man goes out at daybreak, makes the incisions, and fixes his vessels. In the forenoon he collects his juices in a pail, and in the afternoon he "smokes," or makes his india-rubber. A small wood fire is made, and then fed with palm-nuts; over this fire is inverted an earthenware pan of about the size and shape of a 12-inch flower-pot, except that the drainage-hole in the bottom is about 6 inches in diameter; the pan is tilted a little on one side to allow air to enter to the fire. Through the aperture a dense white smoke issues of a peculiar smell. The india-rubber maker now takes a mould or form, shaped according to taste; this he dips into the milk; or, if it be large, he may pour the milk over it. The mould, with some of the milk adhering, is now held and turned about in the smoke for about twenty seconds. By this process the milk is set into a fine thin layer of india-rubber. He continues dipping and smoking until his india-rubber is of the required thickness, or until all his milk is used up. It is then cut and taken off the mould, and put in the sun and air to dry. At first it is of a dark cream colour, but gradually becomes darker. India-rubber loses about one-fourth of its weight in drying.

Before being applied to its various uses in this country india-rubber has to be prepared. For this purpose it is softened by hot water and cut into pieces with sharp knives; it is then passed between grooved rollers, over which either hot or cold water is made to flow. Solid impurities are thus crushed to powder and washed away. The rubber is now dried in a warm room and then *kneaded* or "masticated" by a machine. To convert the masticated rubber into rectangular blocks it is softened by heat, and then pressed into iron boxes or moulds. From these blocks sheets are cut by a machine.

India-rubber in this form is elastic and waterproof, but it

possesses the great disadvantage of becoming soft in hot, and hard in cold weather. It was soon found out, however, that the addition of a little sulphur prevented the material from being affected by changes of temperature. The process of adding sulphur is called *vulcanisation,* and the rubber is said to be *vulcanised.* The india-rubber is placed in melted sulphur and subjected for about an hour to a temperature of 284° Fahr. At this temperature the rubber absorbs about one-tenth of its weight of sulphur, and becomes so changed in its properties that a temperature of 320° Fahr. scarcely affects it, and cold does not make it rigid.

India-rubber may also be vulcanised by exposing the sheets to the action of chloride of sulphur. The sheets are either hung in a leaden cupboard to which the vapour of the chloride is introduced, or they may be dipped in a mixture consisting of one part of chloride of sulphur to forty parts of disulphide of carbon, without heat.

India-rubber is soluble in benzol or wood naphtha, and ordinary mackintosh,* or waterproof cloth, is made by spreading on the textile fabrics layer after layer of the solution. If cotton or linen is used it is usual to incorporate sulphur with the solution, and then to vulcanise with steam heat. If silk or wool is used no sulphur is added; but the dry coating of rubber is brought into momentary contact with the mixture of chloride of sulphur and disulphide of carbon. Double texture goods are made by uniting the rubber surfaces of two pieces by pressure between rollers.

The fine vulcanised "spread sheets" are made by spreading layers of india-rubber solution, already charged with the requisite quantity of sulphur, on a textile base, previously prepared with a mixture of paste, glue, and treacle; vulcanisation is then effected by steam heat. By softening the preparation on the cloth by means of hot water the india-rubber sheet may be removed.

* So called from Mackintosh, the inventor.

India-rubber is employed in an almost endless variety of ways—for articles of clothing, for tents and boats, for tubing and roofing, for the construction of bands and straps, for the manufacture of elastic web, &c.

India-rubber is imported from many countries, but the chief supplies come from Brazil and the West Coast of Africa. The annual imports are valued at £3,500,000.

CHAPTER XV.

COTTON, HEMP, FLAX, JUTE.

COTTON is the name given to the soft white down, or fine cellular hair, attached to the seeds of certain plants, which are indigenous to nearly all tropical countries. The cotton-plants belong to the same natural order as the common mallow, which grows abundantly in our own country. As supplying the raw material for our greatest industry, and for the clothing of all nations, these plants may well claim to be ranked among the most valuable of nature's productions.

The two chief kinds of cotton known in the commercial world are the *Oriental*, or Indian, and *American*. Most of the cotton plants are herbaceous, but a few are tree-like. One species grown in India and China attains a height of nearly 20 feet. The North American species are herbaceous: the seeds are sown in spring, and the cotton is collected from the seed pods as they burst in the autumn.

The cotton most valued of all is "sea-island cotton," grown in the low-lying islands off the coast of Georgia. This surpasses all other cottons in length, strength, and beauty of staple. This cotton is now successfully grown in some of the Southern States, in Queensland, and in Egypt.

Cotton is picked by hand, and the down and seeds are removed together from the pods. The first process in the preparation of cotton for the market is to remove the seeds. This operation is called *ginning*. There are several kinds of *cotton gins* in use. The most simple is that which has long been in use in India. It consists of two wooden rollers placed close together between which the cotton is drawn and the seeds forced out. The *saw gin* consists of a grating of parallel bars on which the cotton is laid, and a series of circular saws which turn underneath the grating so that the teeth of the saws pass between the bars. The cotton is laid hold of by the teeth and drawn through, leaving the seeds behind. The cotton is swept off the saws by a series of stiff brushes turning beneath the saws. The ginning yields one-third of the bulk gathered from the pods as cotton fit for manufacturing purposes. This is pressed into bales for export. The seeds not required for sowing in the next spring are pressed for their oil, and the refuse cake is used for feeding cattle.

The manufacture of cotton into cloth had its origin in the East. More than 2,400 years ago cotton was largely used in the manufacture of articles for clothing in India. The spinning, weaving, and dyeing was of the same primitive kind as that still practised: yet the fabrics produced in the shape of gossamer-like muslins have never yet been equalled in this country. In Europe the cotton manufacture was first attempted in the commercial States of Italy, probably in the early part of the sixteenth century. From Italy it soon made its way to the Netherlands, and was thence carried to England by Protestant refugees about the beginning of the next century. It seems to have at once found a congenial home in South Lancashire, for we read in a book called "Treasures of Traffic," written in 1641, "The town of Manchester buys linen yarn from the Irish in great quantity, and weaving it, returns the same again as linen to Ireland. Nor does

her industry rest here, for they buy cotton-wool in London that comes from Cyprus and Smyrna and work the same into fustians, dimities, &c., which they return to London, where they are sold; and from thence not seldom are sent into such foreign parts where the first material may be more easily had for that manufacture." These goods were woven chiefly in Bolton, and sold in the weekly market to Manchester dealers, who finished the goods and sent them to London. The manufacture at this time was entirely by hand, and each weaver's cottage was a little factory. Linen yarn was used for the warp, and this was purchased already prepared. The female portion of the family carded and spun the cotton-wool for the weft, and the cloth was woven by the man and his sons.

The examination of a piece of calico shows that the *cloth* is built up of *threads* interlaced at right angles (the long threads form the *warp* and the cross threads the *woof*). This points to the two great processes of the cotton manufacture, viz., *spinning* and *weaving*. Spinning is the making of the loose cotton fibre into *thread* or *yarn*, and *weaving* is the interlacing of the yarn to make cloth.

The machines used in the manufacture of cotton goods are too intricate for any attempt at explanation to be made here, but the different processes may be briefly explained.

For making Yarn.

1. *Mixing* and *scutching*.—The cotton from several bales is thoroughly mixed. It is then torn and beaten in a machine to loosen the fibres, and to get rid of dust and dirt.

2. *Carding*, or *combing*.—By several combings and brushings the fibres are laid straight and parallel, and at the same time the short fibres are removed. The cotton leaves the carding machine in a thin ribbon-like film called a *sliver*.

3. *Drawing*.—Several slivers are placed together and by

means of the drawing machine are stretched and drawn out until they are no thicker than one was at first.

4. *Spinning.*—After one or two other processes by which the *slivers* are made longer, thinner, and stronger, and a little twisted, the material is spun into yarn. Spinning consists in still further *drawing out*, and *twisting* into threads.

II. Weaving into Cloth.

1. *Warping.*—A number of *reels*, or *bobbins*, of yarn are wound by a machine in parallel order on a beam, to the length of from three to five hundred yards. This yarn will form the warp.

2. *Sizing.*—The thread is dipped in solution of starch in water to give further strength.

3. *Reaming.*—This consists in arranging and fastening the threads in the warp ready for the next process.

4. *Weaving.*—By this process the threads of the warp are interlaced by cross threads called the woof. The weft thread is carried backwards and forwards by a sort of reel pointed at each end, called a *shuttle.* Instead of passing the shuttle over and under each thread of the warp one at a time, every alternate thread is raised at the same time, and the shuttle passes *under* these and *over* the other half. Then the threads which were first raised are lowered, and the others are raised, and the shuttle is brought back passing *under* the threads it passed *over* before, and over the threads it passed *under* before.*

Raw cotton to the enormous value of about £45,000,000 is imported into this country every year, the main sources of supply being the United States, Egypt, India, and Brazil; and no less than four thousand five hundred million yards of cotton cloth, valued at upwards of £50,000,000, has been the average yearly export since 1880.

FLAX.—Linen is made from *lint*, or *flax.* Flax is the

* For the further processes of bleaching and dyeing, see page 89.

fibre of the inner bark of the Flax-plant—a pretty herbaceous annual growing about two feet high, and bearing bright blue flowers. The flowers are followed by rough seed capsules, each containing ten flat, oval, dark-brown seeds. The preparation of flax from the flax-plant, and the manufacture of linen is the most ancient of all the textile industries. The "remains" of pre-historic times show that the fishing nets and lines were made of flax. Flax occupied a prominent place in ancient Egypt. We read that Pharaoh arrayed Joseph in vestures of fine linen, and the Egyptian mummy cloth was made entirely of flax. Pliny gives the following account of the preparation of the flax. "The stalks themselves are immersed in water, warmed by the heat of the sun, and are kept down by weights placed upon them, for nothing is lighter than flax. The membrane, or rind, becoming loose is a sign of their being sufficiently macerated. They are then taken out and repeatedly turned over in the sun until perfectly dried, and afterwards beaten by mallets on stone slabs. That which is nearest the side, called *stupe* (tow), is inferior to the inner fibres, and fit only for the wicks of lamps. It is combed out with iron hooks until all the rind is removed. The inner part is of a whiter and finer quality." The manufacture was introduced into England from Flanders in the thirteenth century, and thence into Ireland some four hundred years later; and until the close of the eighteenth century, when cotton took its place, it was the most important of the textile industries.

Gathering.—The plants are pulled up by the roots just before the seed pods are quite ripe, when they are just turning from green to pale brown, and when the stalks have become yellow through two-thirds of their length. The stalks are pulled by the hand, and laid evenly in handfuls across each other.

Rippling.—The first process is to remove the bolls, or capsules. This is done, usually on the field, by drawing the

stems through a large iron comb fixed to a plank. The seed-vessels being too large to pass between the teeth are torn off, and fall into sheets placed beneath the rippling apparatus.

Retting, or *rotting*.—The rippled stalks are now tied in small bundles and placed, roots downwards, in pure soft water, free from iron and lime, in dams or smalls ponds constructed for the purpose. The bundles are kept under water by a covering of rushes, or straw, or turf, on which stones are placed. In ten days, or a fortnight, the fibres become loosened and will separate from the woody core. The bundles are now taken from the water, and spread over grassy meadows for about a fortnight, during which time it is turned over. When dry the stalks are carefully taken up, and again tied in bundles, and stacked like corn.

Scutching.—The next process is to separate the fibre from the woody core. This is done either by hand by threshing with a wooden mallet, or in a machine by passing the stalks between grooved rollers. The woody portions are broken to pieces, and beaten and shaken out.

Heckling.—By this process the flax is split up into the finest threads, cleansed, and arranged side by side; while at the same time the short fibres are removed. The operation consists in drawing the fibres through a sort of brush made of fine steel needles instead of bristles. The long silky fibres which remain in the hand of the heckler are called *line*, and the short fibres collected by the brushes form *tow*. The flax is now ready for spinning.

It was formerly the practice, especially in Scotland, for small farmers to grow flax in small patches, and to set, scütch, clean, spin, weave, bleach and finish the linen on the premises; and the same practice still prevails in some countries. Large quantities of flax are grown in Ireland. The chief foreign sources of supply arc Russia, Belgium, Holland, and Germany. The finest quality is obtained

from Belgium; but by far the largest supply is imported from Russia.

HEMP.—The hemp plant belongs to the same natural order as the common nettle and the hop. It is an annual herbaceous plant, the fibre of the bark of which constitutes the hemp of commerce. Much *bast* fibre of other plants is sold under the name of hemp, but the real hemp of commerce is obtained from *Cannabis Sativa.* It is supposed to be a native of India. It grows wild not only in India, but also in northern and western China, on the flanks of the central mountain chains of Asia, and in Russia near the Caspian Sea. It is now extensively cultivated in many European countries, especially in Russia, Italy, Holland, and Germany; and in the United States.

The plant yields three products: fibre, a resinous secretion, and seeds. The fibres are strong, tough, and flexible, and peculiarly adapted for weaving into coarse, strong fabrics, such as sail-cloth and canvas; and for twisting into twine, ropes, and cables. It is prepared much in the same way as flax.

The resinous secretion is developed on the leaves and flowers, but only in hot countries. It possesses medicinal and intoxicating properties, and has long been used in Oriental countries in various forms and preparations for chewing and smoking.

From the seed about thirty-four per cent. of oil can be expressed. This is much used in the preparation of varnishes and in the manufacture of soft soap. It is a *drying* oil, but much inferior to linseed oil. The cake is used for feeding cattle. The chief sources for the supply of hemp are the Philippine Islands, Russia, Italy, and Germany.

JUTE.—Jute hemp, or jute, is a textile material got from the inner bark of a plant belonging to the same natural order as the lime-tree.* It is extensively cultivated in

* The inner bark of the lime yields *bass* or *bast*, from which Russian mats are manufactured.

Bengal, the rich alluvial soil and hot moist climate of this province being very favourable to its growth. Unlike flax, the stalks are cut close to the root with a hook or sickle; and the fibre is superior in quality when the crop is cut in flower. The fibre is prepared much in the same way as flax.

The best jute is of a yellowish-white colour, silky in lustre, soft and smooth to the touch, and long and uniform in fibre. It is inferior to both flax and hemp in strength and tenacity, less even in fibre, and more woody, and not so easily bleached to a pure white.

It is only recently that jute has come into extensive use in the manufacture of textile fabrics in this country. In India this manufacture has long been an important industry among the Hindoos. They make cordage, gunny-cloth, gunny-bags for packing, and even paper, from jute fibre.

Dundee is the chief seat of the jute manufacture in Great Britain. Here the annual output of jute fabrics in the shape of sacking, hessians, tarpaulins, linings, backings for floor-cloth, rugs, carpets, &c., exceeds fifteen thousand miles.

Almost all the jute, about three hundred thousand tons, is brought from India, Bengal alone supplying upwards of *four million pounds* worth.

CHAPTER XVI.

PAPER.*

The origin and early history of PAPER as a writing material is involved in obscurity. The art of making it from vege-

* The word *paper* is derived from the papyrus, or paper reed, which formerly grew in the delta of the Nile. From this reed the Egyptians manufactured writing material. The stem was cut into slices, these were placed side by side, and then others across, the whole being then steeped in water and pressed together, and polished by rubbing with smooth ivory or shells.

table fibre reduced to a pulp appears to have been known to the Chinese as long as two thousand years ago. Paper was made from cotton by the Arabs in the eighth century. Its manufacture was introduced into Europe by the Moors in Spain, and the Arabs in Sicily. In Spanish writings it is called "cloth parchment," a term which well describes the thick material made from cotton fibre. As the manufacture extended northwards in Europe, away from the cotton-growing countries, it became the practice to mix rags with the raw material. Linen also became a paper-making fabric. From the fourteenth century the manufacture of paper may be described as a European industry, and, from its extensive use, it may be inferred that it was made in England in the fifteenth century. The first paper-mills of which we have any record were set up at Hertford and Dartford in the sixteenth century.

Paper may be described as thin layers of fine vegetable fibre. It is made from the following materials:—Linen and cotton rags, refuse flax and hemp, jute, esparto grass, straw, soft wood, and waste-paper. In America a considerable quantity of wool is used. The best paper is made from rags.

The first object the manufacturer has in view is to cleanse, bleach, and reduce the fibre to a fine pulp with water; and the second is to get the pulp into even sheets (of a thickness corresponding to the thickness of the paper required), to be subsequently dried, sized, and rolled.

In the *preparation of materials* the rags have to be *sorted* into linen and cotton, and each of these again into two or three qualities and colours. This operation is performed by women and girls, who, at the same time, cut the rags into pieces about the size of the hand, and remove any buttons, hooks, eyes, or pins. The pieces are next put into a *dusting* machine, where they are torn to pieces with iron spikes, and the dust and dirt beaten out and removed. (Sometimes the

rags are partially cleansed before sorting and cutting.) Next they are *boiled* in large revolving vessels with water to which lime or caustic soda has been added. This process removes grease, and stains, and colouring matter. The boiled rags are now still further torn and reduced to a partial pulp in a *breaking* machine. This machine is so constructed that the rags are made to pass between revolving spikes, like knife-blades, and the material is cut and torn into fine threads. Clean water is kept flowing through this machine. The *half-stuff*, as the torn fibre is now called, is passed into another machine, where it is bleached by a mixture of chloride of lime and water. After another washing the bleached half-stuff is reduced to a fine pulp in the *beating* engine. Various substances are now added to the pulp. (1.) China clay, or pearl-white, to make the paper more solid; this is called *loading* the pulp. Loading weakens the paper, and is not used in hand-made paper, but it fills up the pores and assists the paper to take a better finish. (2.) Sizing materials. These are used for all writing and most printing papers. For machine-made paper resin and carbonate of soda are thoroughly incorporated with the pulp, and then a solution of alum is added. (3.) Colouring matter. To give the blue tinge to white paper either cochineal and ultramarine blue, or magenta and aniline blue, are added. For *blue* paper ultramarine is the pigment added. For *tinted* paper, as a rule, aniline colours are used.

Esparto grass* is treated very much like rags. It is first carefully picked over to remove any foreign matters, and then boiled in a stronger solution of caustic soda than rags. After being thus softened, it is broken and beaten to pulp, and bleached as in the case of rags. Other fibres are treated much in the same way.

It would be unprofitable labour to attempt to describe the intricate machinery used in making this useful commodity;

* Imported chiefly from Algeria and other North African countries.

but the principle is illustrated in the manufacture of *hand-made* paper. *Hand-made* paper is made on a very shallow mould. This mould has a bottom of wire-cloth, supported by stout wires beneath, and a movable frame. The workman dips this mould into the milk-and-water-looking pulp and takes up sufficient to form a sheet of paper of the required thickness. As the mould is lifted from the vat the water drains off through the wire cloth and a sheet of pulp is left behind. The movable frame, or *deckle*, is now taken off and the sheet of pulp is turned over on to a sheet of felt. The pulp adheres to the felt. A number of sheets thus made are piled on each other, with pieces of felt between each pair. When the pile is complete, the whole is subjected to great pressure to remove the water. When sufficiently dried the sheets, which resemble blotting-paper, are removed and dipped into a solution of gelatine for the purpose of sizing. They are again slightly pressed, and dried slowly on lines or poles. Finally, to make them smooth and glossy, they are passed between hot rollers of polished steel.

Machine-made paper is made in a somewhat similar way; but the pulp is allowed to flow out of the vat on to an endless band of wire-cloth. The water is partially drained off, and then the pulp is passed on to felt bands, and pressed between rollers, and then on to other rollers until at the end of the machine it comes out as finished paper.

The *water-marks* are produced by patterns woven into the wire-cloth.

It has been estimated that the yearly production of paper in the whole world amounts to 800,000 tons, of which one-half is used in printing.

CHAPTER XVII.

BLEACHING AND DYEING.

Bleaching is the process by which substances are deprived of their natural colour, and rendered white or nearly so. Clothing made of such materials as "unbleached calico," "brown holland," and so on, on being repeatedly washed with soap and soda, and exposed in the open air to dry, become whiter and whiter until they are scarcely to be distinguished from the ordinary bleached goods. This is practically the old method of bleaching—a method which to some extent is still in use, especially in the bleaching of linen.

The following are the chief processes in the bleaching of cotton cloth—*grey cotton.*

1. The pieces are sewn together, end to end, till several miles of stuff are ready. The cloth is then singed, to remove short threads and downy pile from the surface. This is done by passing it over hot plates, or rollers.

2. The cloth is next boiled several hours under pressure with slaked lime to remove impurities, and then washed and squeezed.

3. Next it is steeped in a weak solution of acid, and then washed and squeezed again.

4. Boiled in a solution of soda-ash and resin for several hours, under pressure, and washed and squeezed again.

5. Steeped in a weak solution of chloride of lime. Washed and squeezed again.

6. Boiled in acid solution, and again washed and squeezed.

7. Opened out and squeezed between rollers placed in hot water.

8. Passed through mucilage of starch made from wheat or Indian corn.*

* Other and sometimes harmful ingredients are too often added to give a fictitious appearance of weight and bulk.

9. Dried between hot rollers.

Some other minor processes follow dependent on the kind of *finish* to be given.

The bleaching of linen is very similar to that of cotton, but requires a repetition of some of the operations.

Straw, for straw-plaiting, is first steamed and then bleached by exposure to the fumes of burning sulphur, viz., sulphurous acid gas.

The bleaching of *wool* and *silk* is more simple than that of cotton and linen. It consists of two processes—*scouring* or *cleansing*, to get rid of the oily matter in wool, and the gummy matter in silk; and *bleaching*, by means of sulphurous acid gas. Wool is cleansed by heating to about 90 degrees in pure soft water to which some substance containing a little ammonia has been added, and rinsing in water. Silk is cleansed by boiling for an hour in a weak solution of soap in water, and rinsing in pure water.

DYEING is the process by which new and permanent colours are given to substances such as cotton, woollen, linen, and silk goods. The colouring matters are derived mostly from plants, though some are obtained from the animal and mineral kingdoms. The dye-stuffs are found in all the organs of plants: thus in the madder and turmeric they are obtained from the roots; in logwood, Brazil wood, and fustic they are found in the wood; in quercitron in the bark; in safflower and saffron they are furnished from the flowers; while indigo is derived from the juice of the leaves and stalks.

The most important *red* dye-stuffs are madder, logwood, Brazil wood, cochineal, and the aniline dyes. Of the *yellow* dye-stuffs, quercitron and fustic are the most important, while indigo is the chief of the *blue* colouring matters.

Of the various dye-stuffs a few, like indigo and the aniline dyes, are capable of giving a *permanent* colour when the material is simply placed in a solution of the dye. The

finest shades of mauve, magenta, and purple may be obtained by placing wool, or silk fibre, in a solution of aniline dyes. But the greater number of the colouring matters may be removed by washing. Thus, if calico be dipped in madder, or flannel in cochineal solution, the colouring matter may all be removed by washing. It becomes necessary therefore to adopt some method of *fixing* the dye to the fabric. This is effected by the use of various substances which possess a strong tendency to attach themselves to the fibres of the texture, and at the same time combine chemically with the dye-stuffs. The substances which thus form a kind of connecting link between the materials and the dye are called *mordants* [Fr. *biting*]. Mordants are very numerous and they are applied in a great variety of ways. (Salts of iron, alumina, tin, and copper, are the principal.) The same mordant with different dyes produces different tints, and the different mordants produce different colours with the same dye. The more common plan of dyeing is to mordant the goods before applying the colouring stuff, but occasionally the mordant and the dye are mixed together.

As one example of the more usual method, we may take the dyeing of calico black with infusion of logwood. The cloth is first passed through a hot solution of sulphate of iron (green vitriol), and then squeezed between rollers to remove the excess of mordant. Next it is passed through lime and water, and then washed to remove excess of lime. The calico is now a buff colour; but pass it through an infusion of logwood, and it becomes an intense black.

It is not necessary that the whole of the cloth should be mordanted. If the mordant be mixed into a stiff paste with British gum, it may be put on in patterns by the aid of suitable machinery. In other words, the patterns may be *printed* on the cloth. If the cloth thus prepared be allowed to dry, and is then passed through the dye-vat and afterwards well washed, it is found that the mordanted patterns only

retain the colour. This kind of pattern dyeing is an extensive industry in Manchester and other "cotton towns." It is known as "calico printing."

CHAPTER XVIII.

TEA, COFFEE, AND CHOCOLATE.

TEA.—The tea-tree is an evergreen bushy shrub having lance-like pointed leaves with saw-like edges. The flowers are white, with yellow stamens, and are slightly fragrant. The seeds, which are enclosed in a woody shell, are oily and covered with a hard smooth skin. The bushes are kept down by pruning to an average height of from three to five feet.

The tea-shrub is probably a native of China and Japan. We can trace its cultivation in China back to the fourth century, and it was introduced into Japan early in the ninth century if not earlier, and from these two countries the leaf was exclusively obtained till within the last fifty years. We do not hear of the introduction of tea into England in any quantity till 1657, when its price in sovereigns was greater than it is now in shillings. Its very high price kept its use limited to the wealthy classes for many years; now it is used habitually or occasionally by half the human race.

In the year 1834, the tea-plant was discovered growing wild in Upper Assam, and now its cultivation, both there and on the slopes of the Himalaya and Neilgherry Mountains, has become an important and extensive industry.

The shrub requires a warm climate, and a rich, deep and damp, but well-drained soil, to bring it to perfection. Like the coffee plant, it grows best on hill-sides. The young trees are planted in rows from four to five feet apart, num-

bering about two thousand trees per acre. After the fourth or fifth year an acre will yield from 240 to 320 pounds of tea. The picking commences in April, and is continued till October.

The preparation of the leaves consists in drying, rolling, fermenting, and roasting. The manufacture of tea in India is somewhat less complicated than in China. The young shoots, with three or four leaves attached, are plucked with the finger and thumb, old leaves being discarded. These are placed on mats and exposed to the sun for a few hours, till they become sufficiently flaccid to bear rolling without breaking. They are next rolled with the hands on a deal table, and then thrown into a loose heap and covered with mats or carpets to allow of a slight fermentation. The leaves are now roasted for a few minutes in shallow metal pans, and then thrown quickly on the table to be rolled again while hot. This process is repeated, and finally the now black leaf is dried by exposure to the sun, or over charcoal fires. Either black or green tea may be prepared from the same leaf. If the latter is required, the process of fermentation is dispensed with, and the leaves are more rapidly dried and rolled. Formerly large quantities of colouring matter were used to heighten the colour, and give the tea a bright green appearance. Such coloured tea was never used by the Chinese themselves.

Many different sorts of tea are imported, but those best known are Pekoe, Souchong, Congou, and Bohea, all black teas. In greens Hyson and Gunpowder are the most familiar. The youngest, and hence the smallest leaves. produce the most delicate flavoured teas. The earliest pickings of all seldom leave China, they are reserved for home use and as presents for friends. A small portion is sent by caravan to Russia, and is said to fetch two guineas a pound. The main picking forms Congou, and this is the main bulk of the British imports. Pekoe and Souchong are finer and dearer

kinds, the result of earlier pickings. Bohea is much coarser. Hlassa brick-tea is pressed into the form of a brick. It is prepared for use with butter and salt, and is preferred to all other kinds by the natives of Central Asia and Tibet.

The infusion of tea has very little nutritive value, that is, it is not in any sense a food. It increases the respiratory action, promotes perspiration, and therefore tends to cool the body, and stimulate the brain to greater activity.

China and India (Bengal and Burmah) are the chief sources of tea. From these two countries about two hundred million pounds of tea, of the total value of £11,000,000, are imported every year.

Coffee.—The coffee-tree is indigenous to Abyssinia, where it still grows wild. From Abyssinia it appears to have been introduced to Arabia and Persia, in which countries coffee soon became the national beverage. The great demand for its seeds has led to its cultivation in most of the tropical countries where a suitable situation can be found. Brazil, Java, Sumatra, Ceylon, Jamaica, and Arabia are the great coffee-growing countries. One species of the coffee-plant grows wild in great abundance along the whole of the Guinea coast.

The common coffee-tree is an evergreen plant, with smooth shining leaves five or six inches long, resembling those of the Portugal laurel. The tree naturally grows to a height of eighteen or twenty feet; but in cultivation is kept down by pruning to a height of about six feet. It bears small pure white flowers characterized by a rich fragrant odour; but they quickly fade. The fruit which follows is a fleshy berry having the appearance and size of a small cherry. As it ripens it assumes a dark red colour. Each berry contains two seeds embedded in the yellowish pulp, and enclosed in a tough skin, called the parchment. The seeds, or "beans," which constitute the raw coffee of commerce, are curved at the back, and flat and deeply furrowed at the front.

The cultivation of the coffee-plant requires much care. The plants begin bearing in the second year, and in the third should yield a fairly remunerative crop. The berries are ready for gathering when the skin begins to shrivel up. Immediately after picking they are taken to the "pulping" house. Here the pulp is crushed and bruised between roughened rollers, and then washed away by a stream of water. The beans are now dried in the sun, and as soon as practicable freed from the "parchment" by passing between wooden rollers, and winnowing away the broken skin. The shelled coffee is now passed along a tube perforated with holes, of regularly increasing diameter, which separate the beans into various sizes. Lastly, they are hand-picked to free from defective seeds, and packed in bags ready for export.

A tree in good bearing will produce about two pounds of berries annually; but very much depends on situation, soil, and climate. The trees grown in dry situations, such as hill-sides, yield less weight of berries, but of superior quality. In the low moist lands the yield is greater, but the quality inferior. Raw coffee seeds are tough and horny in texture, and of a greenish colour. They are entirely devoid of the aroma and taste which characterize the roasted seeds.

Roasting is an operation of the greatest nicety. On its success the pleasant flavour of coffee depends. If the seeds are roasted too little the aroma is not sufficiently developed, while if roasted too much it is partially destroyed. The roasting is conducted in iron cylinders, which are made to revolve over the fire so that all the beans in turn may be exposed to the same degree of heat. The coffee beans when roasted may have three degrees of shade—reddish-brown, chestnut-brown, and dark brown. The dark brown gives the fullest, but not the most delicate flavour. Coffee should be roasted the shortest practicable time before required for use, for the roasted beans deteriorate in flavour; and the

grinding should immediately precede the making, for ground coffee rapidly loses its aroma. If coffee must be kept in its ground state a clean stoppered bottle answers best.

Ground coffee in the past has been subject to extensive adulterations, and this may partially account for the declining popularity of this beverage in Great Britain. Roasted and ground roots of dandelion, carrot, parsnip, beet, corn, peas, beans, acorns, &c., are among the adulterating substances. The mixture of chicory* with coffee can scarcely be looked upon as an adulteration, for many persons prefer the mixture to the pure coffee. It gives to the decoction additional colour, bitterness, and body. The admixture of chicory with coffee is readily detected by placing a few grains in cold water. Chicory betrays itself by the deep brown stains in the water, while coffee is insoluble.

It is a curious fact that cocoa, coffee, and tea were all introduced into this country within a few years of each other. Cocoa was brought from South America *viâ* Spain, coffee from Arabia *viâ* Constantinople, and tea from China by the Dutch. The first coffee-house was opened in London in 1652, and coffee soon became a favourite beverage.

The total annual world's produce of coffee berries is estimated at about 500,000 tons, of which 70,000 tons, valued at £5,000,000, are received in this country.

COCOA, OR CACAO.—The cacao-tree, *Theobroma* † *cacao*, is a small evergreen tree which grows in the West Indies, in Central America, and in the tropical parts of South America. It abounds in the forests of Demerara. The tree requires careful cultivation. It needs a rich soil and humid climate, and protection from cold winds and violent storms. This

* The chicory or succory plant is a native of our own country. It grows on chalky soils, and by the dusty roadside. It is known by its large and bright blue colours, and toothed leaves. It is cultivated to some extent in Yorkshire, but its roots—for roasting and grinding—are mainly imported from Belgium and other continental countries.

† *Viz.* food for the gods.

protection is given by planting other trees for the purpose. The cacao-tree begins to bear about the sixth year. Buds, flowers, and fruit in all stages of growth are to be found on the same tree, hence ripe fruit may at all times be collected; but the chief harvests are in June and December. The flowers grow in clusters on the trunk and main branches. The pods, in which the seeds are enclosed, are from seven to ten inches long, and three or four inches in diameter. They are hard and tough and ridged longitudinally, and contain from twenty to forty seeds attached to a central core, and are embedded in a mealy pinkish-white pulp.

The *seeds*, or *nuts* (constituting the cocoa-beans of commerce), are enclosed in a thin, hard, and brittle shell. When removed from the pods they are put into boxes, or buried in the ground for about two days, during which time they ferment. Great care must be taken not to allow them to *heat* too much, or the flavour would be spoiled. They are next dried in the sun, roasted and crushed, and then winnowed and picked over by hand to remove broken shells and any mouldy or discoloured fragments. The broken pieces of kernel are called *nibs*. Sometimes the kernels are ground into a fine meal, of which a paste is made. This paste is allowed to harden, when it is cut into thin slices forming *flaked cocoa*.

When the oil has been extracted before grinding to powder, the preparation is called *essence of cocoa*, or soluble cocoa. *Nibs* require long boiling, but *soluble cocoa* can be prepared by merely pouring on boiling water and stirring. Soluble cocoa formed into a paste, with the addition of sugar and a little flavouring matter, is called *chocolate*.

Cocoa is brought chiefly from the West India Islands, Brazil, and Ecuador; and, in a manufactured state, from France and Holland. In all about 10,000 tons, valued at about *three-fourths of a million* pounds, are annually imported.

CHAPTER XIX.

SPICES.

Cloves.*—The trees and shrubs of the myrtle tribe are generally aromatic, and many of them yield a pungent volatile oil. They are mostly tropical, or sub-tropical plants. The unexpanded flower-buds of one tree of this natural order, a native of the Moluccas, or Spice Islands, constitute the cloves of commerce. The tree is a beautiful evergreen, bearing large oblong leaves, and a profusion of crimson flowers. The flower-buds are at first of a pale yellow colour, but they change gradually to green, and then to bright red. As soon as the latter colour is developed the flower-buds are ready for plucking and drying. The clove is now grown in the West India Islands, and in Java and Sumatra in the East Indies. It is only within a very limited range of climate, however, that the clove acquires its full aromatic flavour.

Every part of the clove-tree abounds with aromatic oil; but it is most plentiful in the unexpanded flower-buds, from which 18 per cent. of oil may be extracted. The clove of commerce is of a deep brown colour, and possesses a pungent taste, and powerfully fragrant odour.

Allspice.—From another tree of the myrtle tribe, a native of the West Indies, *allspice*, pimento, or Jamaica pepper, is obtained. Allspice is the dried berry; it is so called because it is considered to have the flavour of cloves, cinnamon, and nutmeg combined. It is mildly pungent, and agreeably aromatic.

Cinnamon is the dried *inner* bark of an evergreen shrub belonging to the same tribe as the English bay-tree. It is almost exclusively a product of Ceylon, whence about seven

* So called from the French word *clou* (a nail), on account of its resemblance to a nail.

hundred tons are imported annually. The bark is taken from the twigs of eighteen months' or two years' growth, cut into lengths of about a foot, and then the outer and middle layers of bark are removed by scraping. The smaller pieces are then placed beside the larger, and the whole dried in the sun and packed in bundles for exportation.

The NUTMEG was an article of commerce in Europe long before anything was known of the species or habitat of the tree from which it was obtained.

It is the seed of an evergreen tree which grows wild in the Moluccas or Spice Islands, especially on three small islands called Banda Islands. On these islands nutmeg trees are now cultivated; but large plantations are also to be found in Sumatra, and in India. In Banda the trees are planted under the shade of lofty canary trees. Here the shade, the light volcanic soil, and the excessive moisture exactly suit the nutmeg. The trees blossom and bear fruit all the year round, but the chief harvest is in the later months of the year. The ripe fruit is pear-shaped, but in size and colour it resembles the peach. The fleshy covering of the "stone" or "nut" is about half an inch thick. This bursts at the sides, splits into two halves like the nectarine, and exposes a shining black nut enveloped in a leafy network of a brilliant red colour. This network is carefully stripped off and dried. It then forms the *mace* of commerce. The nut consists of a thin hard shell and a kernel. The shell is considerably harder than that of the filbert, and, before drying, could not be broken without injuring the kernel, which is the nutmeg itself. The nuts are dried in the sun, or in a drying-house, until the kernels shrink so much that on being shaken they rattle within the shell. The latter are now broken with wooden mallets on flat boards, and the nutmegs picked out and sorted. The inferior kernels are set aside for the extraction of the oil called "oil of mace;" the finer kernels are rubbed over

with dry lime, and packed for export. The yearly imports of nutmegs into the United Kingdom exceed half a million pounds, and of mace sixty thousand pounds.

GINGER is the rhizome, or underground stem, of a reed-like plant growing to a height of three or four feet. It is grown in most tropical countries, but especially in the East and West Indies. That brought from Jamaica is considered the best. The ginger of commerce is classed as black and white—the coated and the uncoated. For the first kind the irregular palmate rhizomes are simply washed and dried in the sun. For the second kind the pieces are washed, scraped, and sun-dried, and then often bleached by the use of sulphur fumes, or chloride of lime. The whitewashed appearance it presents is due to a coat of whitewash applied ostensibly to give the ginger a better appearance, but more often to hide an inferior article.

The properties of ginger are very marked. It has a pungent aromatic odour, and a hot biting taste. It breaks with a short mealy fracture, and presents on the broken surface numerous short bristly fibres. It is used as a spice or condiment, and occasionally in medicine. "Preserved ginger" is an agreeable sweetmeat, the *young* rhizomes preserved in syrup being considered a great delicacy.

Our chief sources of supply are India and the West India Islands.

CHAPTER XX.

OPIUM, QUININE, AND CAMPHOR.

OPIUM is the dried milky piece obtained from the seed capsule of the opium-poppy. This plant is grown chiefly in Asia Minor, India, and China. The poppy grows freely in

temperate climates, but the yield of opium is insufficient to make its cultivation profitable. The species of poppy grown, the method of cultivation, and the quality of the opium produced vary very much in different countries. In Asia Minor there are three sowings made in the year, from October to March, so that the crops may come in succession. The first crop is usually the most profitable. The plants bloom from May to July, according to the climate; the petals of the flowers fall in a few hours, and the capsules grow so rapidly that the opium is ready for collection in from ten to fourteen days. It is always collected by hand. Shallow incisions are made in the capsules in the afternoon and evening, and the juice which exudes is collected the next morning by scraping with a knife, and transferring to a leaf. When one leaf is filled, another leaf is pressed on the top, and the collection is placed in the shade for a few days to dry.* The whole of the collection must be made in a few days, while the capsules are in a condition to discharge their juice. When the pieces are sufficiently dry they are packed in cotton bags, sealed, and carried to Smyrna or some other port. Here it is carefully examined, and sorted according to quality, before exportation. Turkey opium is generally of superior quality, and as such is used principally for medicine in this country.

The production of opium in India is a Government monopoly. It is open to every one to cultivate the poppy, but the cultivator is compelled by law to sell the opium to the Government at a price fixed by the agent beforehand. The usual price paid by the Government is about 3s. 6d. per lb.; but the selling price is quite three times that amount. In the valley of the Ganges nearly a million acres are under poppy cultivation. The seed of the poppy is valuable. It yields from 35 to 42 per cent. of oil.

The greater portion of the opium produced in India is

* In India the juice is collected in earthenware vessels.

purchased by the Chinese; and notwithstanding this, a still larger amount is produced in China, and the cultivation of the poppy is still making rapid strides in that country. Opium is also a product in Persia, Egypt, and some other countries.

The chief value of opium is as a medicine to relieve pain, to allay irritation of the nervous system, and to produce sleep. *Morphia,* or *morphine,* is the active principle, and the quality of the opium is judged by the quantity of this substance it contains. *Laudanum,* a crude preparation of opium in spirits of wine, is the form in which opium is most largely used. It is poisonous, but, like many other poisons, its habitual use seems to destroy much of its effects, so that the dose has to be constantly increased. The habit of taking opium to relieve pain, or produce sleep, is difficult to break off.

Much opium is used in medicine, but far greater quantities are consumed in chewing and smoking. Opium chewing is chiefly practised in India, Persia, and Asia Minor; opium smoking is more prevalent in China. It is estimated that nearly 10 per cent. of the population of India are habitual opium chewers, and nearly 25 per cent. of the Chinese are opium smokers. Indian opium is more highly prized by the Chinese for smoking than the produce of their own country. Opium chewing and smoking seems to be very much like smoking tobacco, and, used in moderation, it is said to be no more injurious than the latter practice. Carried to excess, it is certain ruin to mind and body. Opium for use in this country is imported mainly from Turkey.

PERUVIAN BARK—from which we obtain one of the most valuable medicines, QUININE—is taken from the cinchona, an evergreen tree, which grows wild in the dense forests of the mountainous regions of the tropical Andes. It is usually found at heights varying from 2,000 to 8,000 feet. The trees grow either isolated or in small clumps, and the work-

men in their search have to cut their way through almost every step they take in the forest. When a tree is discovered it is cut down, and the whole bark of the stem and branches is secured. The thinner bark of the branches, which makes the rolled bark, is merely dried in the sun, when it naturally takes the form of hollow cylinders. The squares from the trunk are subjected during the process of drying to great pressure. They are alternately dried and pressed until in a fit state for the market. The bark is now carefully tied in bundles, and sown up in woollen canvas, to be carried by the men out of the forests. When they reach the town depôts the bundles are opened and the bark sorted, and repacked in rough chests covered with hides for exportation.

The enormous consumption of these barks, and the wasteful and reckless manner in which the trees are destroyed to procure them, led to the fear that the supply would soon become exhausted. Efforts have therefore been made, and with considerable success, to cultivate the tree in Southern India, Ceylon, British Burmah, and on the southern slopes of the Himalayas. In the Neilgherry plantations alone several million cinchona trees are now under cultivation.

The preparation from the chinchona bark most extensively employed in medicine is known as *Quinine* (Sulphate of Quinine). The discovery and the use of quinine made quite an epoch in the history of medicine. Besides being a specific in ague and fevers, it is used as a tonic to brace up the nervous system, and to recruit the general health.

Peruvian bark is obtained chiefly from South America, and from Ceylon.

CAMPHOR.—Of the many *secretions* stored up in plants camphor is one of the most important. It may be obtained in small quantities from the roots of thyme and sage; but the main supply is derived from two trees, the first, the camphor laurel, growing principally in China and Japan, and most abundantly in the island of Formosa; the second,

a tree belonging to the same family as the limes, a native of Sumatra and Borneo and the Malay peninsula.

The camphor laurel is about the size of our English oak. Every part of the tree is strongly impregnated with camphor, but the roots yield the greatest quantity. These are cut in pieces and placed in an iron retort, with an earthen or wooden top. In the hollow of the top, or lid, hay or straw is fastened across, so as to form bars or cords, and the whole is made air-tight by means of hempen packing. When the retort gets hot, the camphor escapes as a vapour, and is condensed on the straw. The camphor thus collected is of a brownish-white colour, and needs to be purified by a second distillation. In China this is effected by placing alternate layers of camphor and dry earth in a copper still, and covering the whole with a vessel made of straw, but covered on the outside with clay. On heating, the camphor is again vapourised, and then collected on the straw, where it crystallises.

From the trees in the Sumatra, Borneo, and the Malay peninsula, camphor is obtained in pure crystalline masses without the trouble of distillation. It is found solid in cavities or fissures, sometimes a foot and a half long, within the trunk. These cavities, however, cannot be discovered without sacrificing the trees. The trees are cut down and then split by means of wedges. Often, however, the tree is hacked and hewn to pieces without avail. The cavities are filled with a black pitch-like substance of no value.

Camphor has a penetrating and aromatic odour, and a strong unpleasant taste. It is very sparingly soluble in water, to which, however, it imparts its peculiar odour and taste. It is soluble in alcohol and in oil, and 100 parts of spirit will dissolve 120 parts of camphor; the solution forms "spirits of camphor." If this solution be poured into water the camphor reappears in white flakes. Camphor is so tough that it is reduced to powder with great difficulty. The addi-

tion of a few drops of oil or spirit, however, destroys the toughness. It melts at a moderate temperature, but passes off at once as vapour. It burns readily, even when floating on water, and gives off quantities of smoke.

Camphor is used as a medicine,* and it enters largely into the composition of varnishes used by painters. Small insects cannot endure the powerful scent of camphor, and it is used, therefore, for the protection of dried specimens in cabinets and museums, and for the preservation of furs and woollen fabrics from the depredations of moths.

CHAPTER XXI.

MISCELLANEOUS ARTICLES—INDIGO, OAK-GALLS, CORK TIMBER, FRUITS, LIQUORICE.

INDIGO.—The beautiful blue vegetable dye known as indigo may be derived from the leaves of several plants; but the indigo of commerce is prepared mainly from a plant of the pea and bean tribe, which is cultivated for the purpose in Bengal. The *Indigofera tinctoria* is a herbaceous plant, growing from three to five feet in height. The indigo-yielding principle resides chiefly in the leaves, and these are most gorged just as the flowers are beginning to open in June and July, when the indigo harvest commences.

The plants are cut down and tied in small bundles, and conveyed at once to the factory. This consists of two ranges of large vats or tanks, twenty feet square and five feet deep. One range is at a lower level than the other. The bundles are placed in water in the vats of the upper range and kept

* "Camphor balls," or a few drops of spirits of camphor on sugar, if taken in time, will often ward off a cold. Camphorated spirit is also a good remedy for chilblains and burns when the skin is not broken.

down by cross-bars. Fermentation soon sets in, which is allowed to continue for from nine to fourteen hours, according to the temperature. When the process has reached a certain point, of which the manufacturer judges by experience, the liquid assumes a fine yellow colour. It is then drawn off into the lower tanks, and lashed furiously with long bamboos to expose fresh surfaces to the air. The liquid gradually assumes a green colour, and broad flakes of indigo begin to appear and sink to the bottom. When the process is complete, and the indigo all settled at the bottom, the clear liquid is run off. The indigo is then taken and raised to the boiling point. It is now allowed to rest for a day, then boiled for three or four hours, and lastly drained on calico, and pressed and dried.

Bengal indigo of good quality is of an intense violet-blue colour; it breaks easily, and the fracture shows a peculiar coppery lustre.

Indigo is the most important of the colouring matters used in dyeing and printing calico. Bengal and Madras are the chief sources of supply.

OAK-GALLS.—Guided by a remarkable instinct, insects deposit their eggs in such positions and places, that when the young grubs appear they may find a sufficient supply of suitable food. The females of one species of fly known by the name of Cynips, or Gall-flies, deposit their eggs *within* the leaves and young shoots, and even the acorns and catkins of the different varieties of the oak-tree. The *ovipositor*, or egg depositor, of this insect consists of three lanceolate plates, arranged to form a triangular tube, which pierces the tissues of the plant, and through which the eggs are conveyed to their destination. The wound made by the ovipositor sets up a kind of local irritation and inflammation; around this a swelling takes place, and very soon the eggs are within a globular fleshy chamber, the walls of which form a storehouse of food for the future grubs. These excres-

cences vary in form, size, and structure, according to the species of gall-fly producing them. The "oak-apples" found on the leaves of the English oak are smooth and round, and about the size of large marbles. The "nut-galls" of commerce are formed on the young twigs of a small oak which flourishes wild in Asia Minor, and in other countries bordering the Mediterranean. The best "Aleppo-galls" are hard brittle balls, about half an inch or less in diameter, ridged and warty on the upper half, and light brown to greenish-yellow within. The galls are gathered before the full-grown larvæ have tunnelled a way of escape. In this state they are termed *blue* galls. The *white* galls, viz., those gathered after the escape of the insect, are lighter in colour, less in weight, and altogether inferior in quality to the blue galls. Commercial gall-nuts yield from one-fourth to three-fourths of their weight of *tannin*, and about *two* per cent. of *gallic-acid*. Tannin is present in the bark of many trees, especially in that of the oak; it is used for tanning leather. The tannin of gall-nuts is used to some extent on the Continent for tanning purposes.

Gallic-acid, as we have seen, exists ready formed in small quantities in gall-nuts. It may, however, be readily obtained from tannin by allowing an infusion of gall-nuts to stand in a warm place for some weeks exposed to the air. Gallic-acid is an essential ingredient in the manufacture of black ink, and the first process in the manufacture is the fermentation of the powdered nut-galls to produce gallic-acid.

CORK.—The layer of tissue found immediately beneath the epidermis we have described as consisting of cellular tissue. This layer is usually thin; but in the bark of one species of oak it attains to a remarkable thickness. On this account the tree is named the cork-oak. The cork-oak grows wild in the countries bordering on the Mediterranean Sea, but more especially in Spain and Algeria.

When about five years old the corky layer begins to make

very rapid growth, and when the tree has attained the age of from fifteen to twenty years it is ready for its first stripping. The operation of barking does no harm to the tree, provided the inner bark is not injured in the process. The stripping is done in July and August. Incisions are made in the bark all round the tree at regular intervals, then a longitudinal cut is made from top to bottom, and the bark is detached in cylindrical pieces. The first stripping is rough and woody in texture. It is used for ornamentation under the name of virgin cork. The second stripping, which is made from eight to ten years after the first, is also coarse in texture; but the quality of the cork improves with each successive stripping, until the trunk has been denuded of its covering for the eighth or ninth time.

When the cork has been removed the outer surface is scraped and cleaned; it is then ready for charring and flattening. The flattening is done by pressure on a flat surface. It is then dried and charred over a brisk fire in what is called the "burning yard." The burning must be managed with care, else the cork is burned and blackened. The charring causes the bark to shrink, and the pores to close up, rendering the cork impervious to fluids.

Cork possesses a combination of properties which peculiarly fit it for many and diverse uses, for many of which it alone is found applicable. Because of its compressibility, elasticity, and practical imperviousness to air and water, it is used as stoppers for bottles and barrels. Because of its specific lightness, combined with strength and durability, it is used in the construction of life-buoys, cork jackets, life-boats, and other life-saving apparatus. Because of its specific lightness, softness, and non-conductive properties, it is used for hat-linings, inner soles of shoes, &c.

The chips and cuttings are not wasted; they are ground up and mixed with india-rubber to form kamptulicon floorcloth; or they are ground and mixed with linseed oil, and

spread over a canvas backing to form linoleum. Our large supplies of cork are obtained from Portugal, France, and Spain.

TIMBER.—The word timber is used in a twofold sense. It is applied to such trunks of trees as are fit, from their size and quality, to be sawn into planks for building and other purposes. The planks themselves are also often called timber.

Although not the strongest or the most durable, the timber obtained from the great family of cone-bearing trees—the firs and pines—is the most valuable in an economic sense because it is plentiful, and therefore cheap; and it is easily worked. In Sweden and Norway, in Russia and Germany, and especially in Canada, there are vast pine forests from which our main supply of this timber is drawn; but there are also valuable forests of these trees on the slopes of the Alps and Pyrenees, and in Scotland.

The chief timber-trees in these forests are the Scotch fir, the spruce fir, the silver fir, the Weymouth pine, and the larch. The Scotch fir produces the most valuable timber. It is called by various names—Riga fir, red pine, and red deal. It is obtained chiefly, though not exclusively, from Sweden, Norway, and Russia. The Weymouth pine is the great pine of the Canadian forests. Its timber is the yellow pine of American commerce. It is not so flexible, durable, or elastic as the red pine; but it is more easily worked.

The timber of the spruce and silver firs is called white deal, or white Norway, Christiana, and Dantzic deal. White deal does not readily warp, and is useful for flooring. The spruce fir is much used whole for scaffolding, ladders, small masts, mining timber, &c. The wood of the larch is noted for its durability.

First among the hard-wood timbers is the common British oak. In strength and durability it surpasses all other woods. Oak timber is imported from America, but it is much in-

ferior in quality to the English oak. Other valuable hard woods of this country are the ash—much used by coachbuilders and wheelwrights, and for making handles for tools; the elm, a timber noted for its durability under water; and the beech, used in making furniture. Of the hard woods imported, teak—"the king of the Indian timber-trees"—is the best. Mahogany from Central America is much used in the manufacture of furniture.

The total value of timber of all sorts imported into Great Britain in the year 1883 was nearly £18,000,000. The largest supplies are drawn from Canada, the United States, Russia, Sweden, and Germany.

FRUITS.—The *fig-tree* is probably a native of Asia Minor and Syria, but it now grows wild in most of the countries bordering the Mediterranean. The bush or tree rarely exceeds 18 or 20 feet in height, which bears, in the cultivated varieties, broad, rough, and deeply-lobed leaves. Judging from the many allusions to the fig in the Bible, this fruit was probably one of the earliest objects of cultivation. The trees bear two crops annually: the first, or summer crop, from the buds of the preceding year; and the second, or autumn crop, from the spring buds. When ripe the fruit is picked, and spread out in the sun to dry. Those of the better quality are pulled and stretched during the drying process. When ready they are neatly packed in boxes for export. From six to seven thousand tons are brought into this country every year, four-fifths of which come from Asia Minor. The best kinds are shipped at Smyrna, where the fig trade forms one of the chief industries of the people. Figs form a considerable part of the food of the people of Western Asia, both in a fresh and dried state. The inferior sorts are sometimes mashed and made into cakes, to serve as a substitute for bread.

The Orange.—The orange-tree is probably a native of India and China. It is still found growing wild in the

jungles of Northern India. It is abundantly cultivated in Spain and Portugal, Sicily, the Azores, Jamaica, and Florida; and to a less extent in almost every other tropical and sub-tropical country. By far the largest quantity of oranges are imported from Spain. The tree is evergreen, and of medium size, seldom rising above 25 feet in height. The flowers, which are of a delicate white colour, appear in summer, but the fruit is not ready for picking till the following year. Hence, flowers and fruit in various stages may be seen on the trees at the same time.

At ten years old the orange-tree will produce 1,000 to 1,500 good oranges, and when full-grown 7,000 or 8,000, and occasionally a large tree will yield twice as many.

There are numerous varieties of the orange; the best of the sweet oranges are the St. Michael's and the Maltese. The Seville, or bitter orange, is grown in large quantities in Spain, and imported into this country and the United States for making marmalade. The rind is made into candied orange-peel.

The leaf, the flower, and the rind of the fruit of the orange-tree all yield volatile oils. The scent of eau de Cologne is due chiefly to oil distilled from the orange-flower. The rind of the Bergamot orange yields *essence of bergamot*, largely used in perfumery.

The Lemon.—The lemon, orange, and citron-trees belong to the same tribe of plants. The lemon is cultivated extensively in the south of Europe. *Citric acid*, obtained from the juice of the lemon, is used extensively in the arts and in medicine. Essence of lemon, used for flavouring and in perfumery, is distilled from the peel. The peel is also candied.

Grapes are grown in immense quantities in France, Spain, Portugal, and Italy, and in some parts of Germany, mainly for the manufacture of various wines. The greatest wine-producing country in Europe is France. The average yield

from 1880 to 1884 was 700,000,000 gallons. Italy stands next to France in the quantity of wine produced. *Raisins* are dried grapes. The fruit, when fully ripe, is scalded in a caustic saline ley (made by passing water through the ashes of burnt vine prunings), and then dried in the sun for about a fortnight. *Muscatel* raisins are dried on the vine, and not scalded. The stalks of the bunches of grapes are partly cut through, and the leaves are removed to allow the sun to have full play on the fruit. The beautiful small *sultana* raisins having no seeds are produced in Turkey. The small grapes known as currants are produced in the Corinthian Islands. The bunches of fruit are about three inches long, and the grapes are about as large as peas.

Liquorice, viz. *sweet root*, is obtained from the root of a perennial plant with herbaceous stalks and purplish flowers. It is indigenous to the more southern countries of Europe, but has been cultivated in this country, particularly in Yorkshire, during the past *three hundred* years. The root is long and succulent, and tough and flexible. Its colour on the outside is greyish brown, but yellowish within. It possesses a sweet, gummy, and slightly acid taste. It is sliced and lightly boiled, and the liquor is strained, and the water evaporated till the residue is of proper consistency. This constitutes the liquorice. In Spain and Italy it is formed into rolls, and packed in bay-leaves. The chief use of liquorice is to give colour and body to "porter." Italy and Turkey are the chief sources of supply.

ANIMALS AND THEIR USES.

ANIMALS AND THEIR USES.

CHAPTER XXII.

CLASSIFICATION OF ANIMALS.

SYSTEMATIC arrangement, that is, *classification*, is the fundamental basis of the study of Natural Science. It would be impossible to study the *structure* and *habits* of the countless animals which people water, earth, air, and sky, their *mutual relationships*, and their *relative importance* in the economy of nature, without first reducing them to something like order.

At first sight classification may appear an easy task. No one could mistake a cat for a cow, a bird for a snake, a frog for a fish, or a spider for an oyster. But in reality the task of classification is one of great difficulty. It is easy enough to distinguish the typical animals of one group from the typical animals of the next group; but there exist pretty nearly always animals which partake of the characters of both groups—"connecting-links" they have been called—which may lay claim to belong to either group. The typical character of one group in certain animals seems, as it were, to shade off, and merge into, the typical character of the next group. Thus, one typical character in the Quadrumana* is the presence of four hands, each having four fingers, with *flat* nails resembling our own, and an *opposable* thumb. Now in the Marmozets, a family of American monkeys, the thumbs of the anterior hands are scarcely at all opposable; and the

* L. *quatuor* and *manus*, four hands.

nails of all the fingers, thumbs excepted, are claws like those of the cat. Again, in the Lemur-like animals, the nails are all flat, except that of the first finger of the hinder hand; and all the thumbs are well developed and opposable to the other fingers; yet in form and appearance these animals look more like squirrels, foxes, cats, &c., than monkeys, and for such they are often mistaken. Writing of one of these creatures, the Rev. W. C. Thomson says: "It was the very epitome of zoology; of the size and colour of a rat, it had the tail of a squirrel, the face of a fox, the membranous ears of the bat, the eyes of an owl, the long, slender fingers of a lean old man who habitually eats down his nails, and all the mirthfulness and agility of a diminutive monkey." Instances might be multiplied out of number of animals which mark the transition, by an almost insensible gradation, from one group to another. The best classification must, therefore, be but an artificial and arbitrary arrangement, and of necessity very imperfect.

Yet, in spite of this, classification is a necessity, because it *shortens* and *simplifies* the labour of the student. A knowledge of a typical member of a group gives us a fair insight into the special characters of the whole group; or, conversely, an acquaintance with the general characters of a group is a passport to an immense amount of information about every individual of the group. Thus, for instance, take the serpent-tribe. We may say of the numerous kinds of serpents that they all have certain characters in common; and that no other known animal possesses the same combination of characters. They all possess a "backbone" composed of numerous pieces *jointed* together by ball-and-socket joints. These bones form the walls of a channel through which the great nerve passes. The channel opens out at one end to form a cavity to hold the brain. Numerous ribs are *jointed* to the pieces of the backbone, but there are no limbs. Compared with that of beasts and birds the blood is

cold. The heart has three cavities. The upper as well as the lower jaw is movable, and the jaw bones are not jointed to other bones, but simply held in their places by the elastic skin. The tongue is thin and forked, and is used only as an organ of touch. The body is covered with scales, most of which are fixed in front only, and can be raised at will; and in such a way that their points are directed backwards; and, as we shall show later on, it is by means of these scales that the animal glides forward. Now these characters being common to the whole group, are of course found in every individual member of the group. Again, a description of the structure and habits of the domestic cat will serve equally well, with slight variations, for the tiger, leopard, panther, and numerous other cat-like animals. In like manner, a description of the teeth of a rabbit, or the stomach of a cow, will apply equally well to a host of other animals, and so on. From the foregoing the teacher will note the advantages to be derived from arranging "object lessons" in Natural History on a definite system.

The first step in classification is to distinguish one animal from another by differences in *form* and *structure;* and the second is to collect into *groups* those whose differences are small.

Animals of the same kind, that is, of the same stock, constitute a *species.* The term is usually applied to animals which produce others like unto themselves. The offspring of a cat is always a cat, and the young of the tiger is always a tiger. So cats and tigers form distinct species. But there are various kinds of cats, and various kinds of tigers, and so we have *varieties* of the same species.

Again, certain species of animals strikingly resemble each other in structure and habits, but differ in minor particulars; thus the cats, the tigers, the lions, and the leopards are very much alike, and we classify these species together to form a *genus*—the genus *Felis.* Resemblances less marked between

genera cause them to be grouped as *families*. Thus we have the genus *felis*, sometimes called the cats proper, together with another genus, the *hyænas*, forming the *cat-family*. [The terms *sub-family* and *tribe* are often used as synonymous with genus.] There are resemblances between the cat-family, the dog-family, the bear-family, the weasel-family, and others, sufficient for the whole to be grouped in one *order*—the order *Carnivora*, or flesh-eating animals. Orders, again, are grouped together to form *classes*. Animals which suckle their young, including some eleven orders, are grouped as *Mammals*, *Birds* form a second class, *Reptiles* a third, and *Fishes* a fourth class. Now all the animals in these four classes agree in one respect—they all possess a jointed backbone. Other animals, such as snails and slugs, insects, spiders, worms, &c., have no backbone. Hence all animals may be classed in one of two grand divisions or *sub-kingdoms*—the *Vertebrata** and *Invertebrata*.

In the very general sketch which follows we shall direct attention to typical animals, and of these such only as will probably be useful for "lessons," leaving the student who desires for information about the less known animals to consult some such popular "Natural History" as that already referred to.†

CHAPTER XXIII.

CLASSIFICATION.—VERTEBRATA I.

The animal kingdom comprises two great divisions, or sub-kingdoms—the VERTEBRATA and INVERTEBRATA—distinguished by the presence or absence of a jointed backbone, or vertebral column, as the chief element in an internal skeleton.

* Latin *vertebra* from *vertere* to turn, so called because the separate bones are so jointed as to possess a certain power of turning on each other.

† Page 5.

In addition to this *internal skeleton* the Vertebrates possess in common a *brain* and a *spinal cord* protected by the skeleton; a *heart* divided into *chambers*, and *red blood:* and they all have an external covering called the *skin.*

The sub-kingdom, *Vertebrata,* is subdivided into *four* great *classes*—MAMMALS, BIRDS, REPTILES, and FISHES; and the animals included in each of these classes possess certain characters in common which, as it were, bind them together.

Mammals feed their young with *milk* formed in their own bodies; the heart is divided into *four chambers;* the *blood* is *warm;* and the skin, except in one tribe, has a covering of *hair.*

Birds lay *eggs,* from which the young are hatched; the heart is divided into *four chambers;* the *blood* is *warm;* and the skin is covered with *feathers.*

Reptiles lay *eggs;* the heart has *three chambers;* the *blood* is *cold;* and the skin is either *naked* or covered with *scales* or *plates.*

Fishes lay *eggs;* the heart has *two chambers;* the *blood* is *cold;* and the skin is covered with *scales.*

The Mammals are divided into orders:—

1. BIMANA, viz., two-handed.—This embraces one species only, consisting of the various *races of men.* Structurally man is separated from the brute creation by his erect stature, and by the possession of a pair of perfect hands. It is in intelligence, however, that the divergence is greatest. Blessed with "an intellect capable of indefinite improvement, man exhibits but little of that instinct which guides the operations of the lower animals. His knowledge is the result of observation, and is matured by thought; his power of speech and the capability of writing are faculties entirely his own, whereby he can communicate his ideas and transmit to posterity the results of his experience. By no means highly gifted as relates to his bodily strength, his swiftness is very far inferior to that of most animals of his size. Pos-

sessing neither strength of jaw nor canine fangs, he is destitute of offensive weapons; and his body being not even clothed with hair, few creatures are, in this respect, left so utterly defenceless; nay, in addition to these disadvantages, he is, of all animals, the longest in acquiring even that strength which is necessary for the supply of his simplest wants; and yet this very feebleness is to him an advantage, compelling him to have recourse to that intelligence with which he has been so highly endowed. Absolutely dependent upon parental care for his support, he must necessarily derive from that source the education of his intellect, as well as of his physical powers, and hence is established an attachment as durable as it is sacred. The very length of his pupilage necessarily gives birth to habits of family subordination, which ultimately lay the foundation of all social order, and tend to multiply indefinitely the advantages derivable from that mutual co-operation whereby he has succeeded in subjecting or in repelling the attacks of inferior animals—in clothing himself so as to defy the inclemencies even of the most rigorous climate, and spreading his race over the surface of the earth." *

2. QUADRUMANA.—The typical members of this order are all characterized by the possession of four *hand-like* feet. Each of these so-called *hands* has long, flexible, prehensile fingers, and a short, opposable thumb. Advantage is taken of the presence or absence of certain striking, but minor characters, to divide the Quadrumana into groups. These characters are the *tails*, *cheek-pouches*, viz. comfortable pockets within the mouth where food can be kept till the animal is ready to devour it; and *callosities*, viz., patches of hardened skin destitute of hair, on which the animal sits. The *man-shaped* monkeys, or apes, such as the gorilla and chimpanzee, have neither tails, cheek-pouches, nor callosities, and their fore limbs are much longer than the hinder. The *baboons*

* Professor Rymer Jones.

have short tails, cheek-pouches, and callosities. The monkeys proper are marked by callosities, and most of them have cheek-pouches and long tails. The *New World monkeys* differ from the monkeys of the Old World in having the openings of the nostrils placed on the sides of the nose instead of at the end, and many of them have *prehensile* tails.

3. Cheiroptera.—The word cheiroptera means "*wing-handed,*" and the animals included in this order are so called because the hands are developed into *wings.* The bones of the fingers are greatly lengthened, and the skin is extended from the body and spread over them in a thin membrane, as the silk is spread over the ribs of an umbrella. The membrane extends backwards to the hind legs and the tail; these organs forming additional supports to the wing structure. This order includes all the *bats.*

4. Carnivora.—This order includes a large number of animals, presenting considerable diversity of structure; but they all agree in being *flesh-eaters.* It includes (i.) those which walk on their *toes*, viz., the cat, dog, and weasel families (digitigrades); (ii.) those which walk on the *soles* of the feet, viz., the bear, racoon, glutton, and badger families (plantigrades); (iii.) those which live partly in water and partly on land, viz., the seals and walruses.

5. Insectivora.—The more common animals which are classed as *insect-eaters* are the shrews, hedgehogs, and moles. This name has been given them because they feed mostly on insects, their teeth being specially adapted for crushing the hard coverings of beetles, locusts, &c. Other animals, however, such as many of the bats, feed on insects.

6. Rodentia.—The rodents, or *gnawing animals,* are so called from the peculiar structure and development of the incisor teeth, which are formed for the purpose of gnawing. The order includes a vast number of animals, probably one-third of all the known mammals; but none of them attain to a large size. The chief *gnawers* found in our own country

are the hares, rabbits, squirrels, voles, rats, and mice. The most common of the foreign members are the beavers, lemmings, hamsters, porcupines, guinea-pigs, prairie-dogs, and marmots.

7. EDENTATA.—The animals of this order possess no canine teeth, many of them have no incisors, and some of them have no teeth at all, hence the name edentata, or *toothless animals.* The sloths, ant-eaters, armadilloes, and porcupine ant-eaters of Australia, constitute this order.

8. PACHYDERMATA.—This collection of *thick-skinned* animals includes a number of dissimilar forms, which agree rather in the absence of other characters than in the possession of any common to all. They have mostly bulky forms, and thick skins. This order includes the horse, elephant, rhinoceros, hippopotamus, tapir, and hog.

9. RUMINANTIA.—This group is distinguished by the possession of *cloven* hoofs, the absence of the incisor teeth in the upper jaw, and the possession of a stomach constructed specially for *ruminating*, or "chewing the cud." Oxen, sheep, goats, antelopes, deer, the giraffe, llama, and camel belong to this order.

10. CETACEA.—This order includes the whales, dolphins, porpoises, which are characterized by their fish-like form, and by the absence of hinder limbs.

11. MARSUPIALIA.—The animals of the preceding groups have been classified mainly in accordance with the nature of the limbs, and the structure of the teeth. This order includes a series of animals having one character in common, viz., a *pouch*, in which the young are carried for some time after birth. In other respects they vary so much that some might be classed as flesh-eaters, others as rodents, others as edentates, and so on. The kangaroos and oppossums are the best-known members of the order.

CHAPTER XXIV.

CLASSIFICATION —VERTEBRATA II.

As we have already pointed out, Mammals are arranged in great groups in accordance mainly with the varying characters of the teeth and limbs. BIRDS have no teeth and the fore limbs are always wings; so that the same characters do not avail us. The forms of the *beak*, and the *legs*, and *toes*, however, serve equally well for a rough classification.

At the head of the class we have the

1. BIRDS OF PREY with *hooked beaks* and *claws*, including such birds as eagles, falcons, hawks, vultures, and owls.

Of those grouped according to the *form of the beak* we have :—

2. CLOVEN-JAWED birds, so called because the beaks open with a very wide gape for the purpose of catching insects while the birds are on the wing. Swallows, swifts, martins, and goatsuckers are members of this tribe.

3. SLENDER-BILLED birds, including the resplendent humming birds of the New World, and the humble wrens of our own country.

4. TOOTH-BILLED birds, in which the upper beak is notched on both sides near the points. Many of our common birds, such as the nightingale, robin, wagtail, thrush, and blackbird, are members of this tribe. They feed almost entirely on insects and worms, but occasionally vary this diet with berries and tender fruits.

5. CONE-BILLED birds having short, thick, *conical* bills, adapted for breaking and cutting seeds. The crows, starlings, finches, larks, and sparrows are familiar examples.

Of birds specially characterized by the *structure of the feet*, we have :—

6. CLIMBING birds.—Commonly birds have four toes, of

which *threc* are directed *forwards*, and *one backwards*. In this group *two* toes are directed *forwards* and *two backwards*—a special arrangement enabling the birds to cling with tenacity, and climb with facility. Parrots, woodpeckers, and cuckoos are climbing birds.

7. The POULTRY-TRIBE.—Most of the birds of this tribe have short blunt nails on their front toes which adapt them for *scraping;* hence they are sometimes called SCRAPERS. They are all grain-feeders, and as they possess no teeth with which to grind, nature has provided a substitute in the internal mill, called the *gizzard*. The typical birds of this group are the fowls, turkeys, pheasants, partridges, and grouse.

8. RUNNING birds.—In this group the toes are usually *three*, or *two*, in number, and directed forwards. The legs are strong, and adapted for running; while the wings are small, and not adapted for flight. The ostrich is the giant of the tribe.

9. STILT-WALKERS, sometimes called *Waders*, having long legs, and long toes.—To this group belong the herons, plovers, and snipes of our own country, together with the storks of Germany and Holland, the adjutant-bird—the scavenger of India, and the brilliant scarlet ibis of tropical America.

10. WEB-FOOTED birds, sometimes called *Water-fowl.*—To this group belong ducks, geese, and swans, and many *marine* birds common on the shores of this and other countries.

The class of REPTILES, or *crawling-animals*, is usually arranged in four great sections:—

1. CHELONIA (chelone, or *tortoise*), including turtles and tortoises, in which the body is always enclosed in a double shield—a back-plate and a breast-plate. The chelonians are endowed with a horny beak instead of teeth.

2. SAURIA (sauros, a *lizard*).—This is the lizard tribe, and

includes (besides the common lizards), guanas, geckos, chameleons, and crocodiles. All these animals are armed with teeth, and the skin is covered with scales.

3. OPHIDIA (ophis, a *serpent*).—To this group belong serpents and snakes—animals covered with scales, but entirely destitute of limbs.

4. AMPHIBIA (amphis, *both*; bioo, *to live*).—This group includes frogs, toads, and newts, and owing to the distinct and curious life-history of its members, is sometimes separated from the other reptiles, and made into a separate *class* called Batrachia (frog-like). In this group the skin is always naked.

The structure of the *internal skeleton* and the character of the *fins* are the characters usually depended on in grouping the lowest class of vertebrate animals, the FISHES. In the majority of fishes the pieces of the vertebral-column are *osseous* (bony); but in some no bony matter is deposited, and the skeleton is composed of *cartilage*. Hence the first great division into OSSEOUS and CARTILAGINOUS fishes.

The osseous group is again subdivided into SPINE-FINNED, and SOFT-FINNED. In the *spine-finned* fishes the first fin-rays of the back are always bony and spinous; and, generally, there are bony spines to the ventral fins. The perch, mullet, mackerel, and the sword-fish are examples of this group. The *soft-finned* fishes, viz., those which possess soft and flexible fins, embrace by far the largest number of the class. The herring, salmon, trout, sole, plaice, turbot, pike, gold-fish, and eels are familiar examples.

Sturgeons, sharks, and rays belong to the *cartilaginous* subdivision.

CHAPTER XXV.

CLASSIFICATION.—INVERTEBRATA.

We have now to glance at the second great division of the animal kingdom—the INVERTEBRATA. This division includes all animals destitute of a jointed spinal column.

"In size, in structure, in shape, the invertebrate animals present an almost infinite variety, and their number is countless. Some have no definite form, and change their shape constantly; some are naked, some have hard tough skins, others are enclosed in shells; some have organs for locomotion, and move with lightning speed; others are fixed, and lead a sedentary life; some have no head, many no limbs; some have no distinguishable organs of sense, while a smaller number have no distinctive organs of any kind, even the stomach being a temporary arrangement. The 'Invertebrates' abound everywhere. Millions inhabit the air; and, in hot countries, become pests to man and beast, though doubtless performing some useful part in the economy of nature. Myriads crawl over the earth, or burrow beneath its surface; many attach themselves to plants, and feed on their juices; and not a few find a home in the bodies of larger animals. The water, again, swarms with these lower forms of creation. Some exist in water of icy coldness, others revel in warm brine-springs; some delight in water clear as crystal, others increase and multiply in the stagnant pool." *

With our limited knowledge of "boneless" animals, anything like a minute natural classification is a very difficult, if not an impossible problem to solve; but fortunately the attempt does not come within the scope of this volume. To complete, however, our broad view of the animal kingdom

* The Rev. J. G. Wood.

we may indicate the *general* characters of the *great* classes into which they are grouped.

Firstly, there is a large group including the *snail, slug, oyster,* and the like which we may characterize as *soft-bodied* —the MOLLUSCA.

Secondly, a still more comprehensive group includes all those animals which, like the *bee, beetle, fly, butterfly, spider, shrimp,* and *worm,* appear to be constructed *externally* of

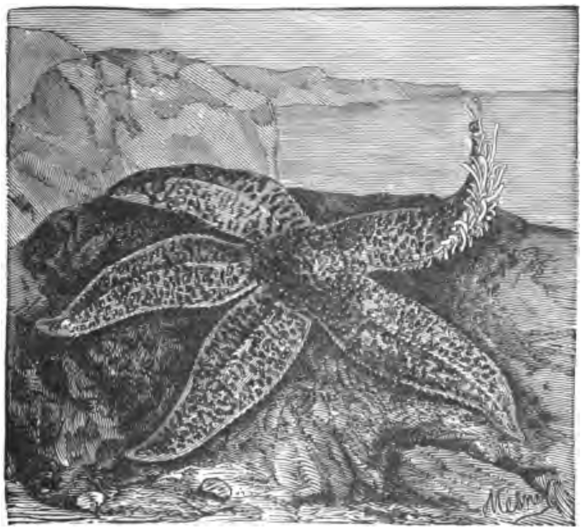


Fig. 89.—Starfish.

ring-like segments united together in such a way as to admit of a certain amount of motion one on the other. These are the JOINTED animals, the ARTICULATA.

Thirdly, all the animals not included in the two preceding groups have been classed together as RADIATA. In the typical forms of radiata, such as the *star-fish* and *sea-anemone,* there is a regular disposition of parts around a common centre—a *radiate* arrangement. But this by no

means holds good in the lowest and least perfectly developed forms of animal life. Most of the members of this group are marine, and a vast number microscopic, and hence not readily available for object lessons. The lessons on the Amœba, Sponge, and Coral, which follow in Part II. will be sufficient illustration, and we pass on to the other groups.

MOLLUSCA.—The creatures included in this great group are all soft and fleshy. Many are naked and defenceless; many more reside in shells which they manufacture for themselves. In all cases the body is covered with an irritable contractile skin, kept moistened by a viscid fluid which exudes from it. Nearly all the molluscs have an extensive fold of the skin reflected over the body, which it covers as with a cloak, or *mantle.* In naked molluscs the mantle is thick and viscid; in *testaceous** molluscs the mantle is thin and transparent. In one large division of molluscs (gasteropods) the under surface of the body is occupied by a broad fleshy disk or *foot,* on which the animal glides slowly

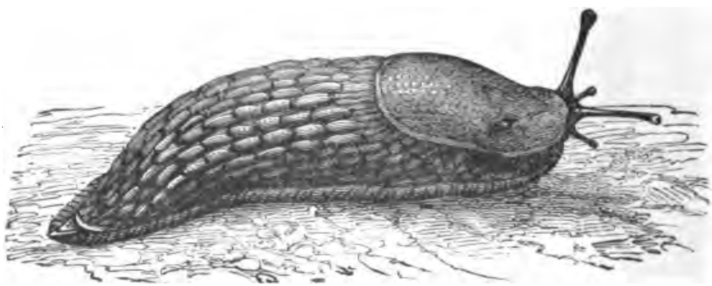


Fig. 90.—Slug.

along. Snails and slugs possess this foot. Cockles are furnished with a tongue-like foot, by means of which they not only leap about on the shore, but bury themselves in the sand. Of the testaceous molluscs some live in *bi-valve* shells, others in *uni-valve* shells. To the former class belong *oysters, mussels,*

* *Testa,* a shell.

and *cockles;* to the latter *snails, whelks, cowries, limpets,* &c. The shells of the former class are joined by a hinge, and the inhabitant has the power of opening and closing the valves at will. Many of the inhabitants of uni-valve shells have a horny or shelly plate attached to their bodies, which serves the purpose of a door when the animal retires within its house. This is well illustrated in the common periwinkle.

ARTICULATA.—The animals embraced in this great division of the animal kingdom possess one obvious character in common. "They are composed of a succession of segments

Fig. 91.—Wood-Leopard Moth, showing segments.

or rings formed by the skin, which from its hardness constitutes a sort of external skeleton." In the lowest forms of this group—the worms and leeches—the skin is soft; but in the insects and spiders it is firm and horny, while in the crabs and lobsters it becomes a veritable solid coat of mail. The *articulata* are arranged in *five* classes, represented by *worms, centipedes, insects, spiders,* and *crabs.* Of these classes the insects embrace by far the largest number of species. Beetles, cockroaches, earwigs, grasshoppers, crickets, dragon-flies, house-flies, ants, bees, wasps, butterflies, moths, and gnats are all well-known examples of insects.

CHAPTER XXVI.

COVERINGS OF VERTEBRATE ANIMALS—SKINS, FUR, WOOL, FEATHERS, HAIR, BRISTLES, &c.

1. The Skin and its Appendages.—All animals endowed with an internal skeleton have the exterior surfaces of the body covered with *skin.* This skin has a structure peculiar to itself, and its functions are many and important. It is double. There is an outer or *scarf-skin*—called also the *epidermis*—and an inner or true skin, the *cutis*, or *dermis.* Between the two there is another thin layer—the *basement membrane*—which may, however, be considered as the outer layer of the true skin. The epidermis consists of numerous layers of microscopic cells, nearly spherical in the layers in immediate contact with the basement, flattened nearer the surface, and nearly flat scales on the outside. The cutis, or true-skin, consists of *fibrous tissue*, viz., fibres interwoven and interlaced into a compact meshwork. The fibrous tissue which binds the skin to the muscles, &c., beneath, is continuous with that of the true-skin, and not to be distinguished from it except by its looser texture. The outer skin contains no blood-vessels, and has no feeling. The cutis contains blood-vessels and nerves; also perspiratory glands, by which the watery fluid from the blood is exhaled through the skin. The fluid passes through corkscrew-like canals, which pass through the epidermis. The epidermis is seen raised from the dermis when a blister forms on the hand, or other part of the body.

In man the skin is for the most part naked; but for the lower animals, which lack the intelligence to clothe themselves for protection against the inclement weather, nature has provided coverings. With the exception of the whale and its relations, which are protected in a different fashion, the skin of most mammals is more or less covered with hair.

Birds have feathers. Some reptiles and a few fishes have naked skins; but most of them are covered with scales, or with armour-plates. Hairs are produced in the scarf-skin, or immediately beneath it. Each hair is formed in a small egg-shaped bag, which is continued outwards to the surface as a sort of tube, called the *capsule*, through which the hair passes.

Hair is called by different names according to its degree of fineness. The finest hair is called *fur;* the stiff hair of the hog we call *bristles;* the large stiff and pointed hairs of the hedgehog and porcupine are called *spines;* and *wool* is a kind of long hair very fine and wavy. Hair is formed of a *horny* matter; and it is the same horny matter which forms the nails on our hands and feet, the hollow horns of oxen and sheep, the claws of the cat tribe, and the hoofs of horses, sheep, and cattle. In some cases the horny matter forms protecting plates, as in the armadillo. On the skin of birds feathers take the place of hairs, and on most of the reptiles and fishes scales, or horny plates, or both.

Skins, fur, wool, feathers, hair, bristles, and even horns and hoofs, form important articles for use in our manufactures. We will therefore look a little more closely at each.

2. Hides and Skins. Leather.—The tanner distinguishes between *hides* and *skins.* Hides are the skins of oxen, horses, and other large animals. Ox-hides are the most valuable. They are obtained from animals slaughtered for food in our own country, and in fact in most civilised countries. They are also imported in vast quantities from South America. Next in value to ox-hides are sheepskins, and it is a curious fact that the value of the skin is in inverse ratio to the value of the wool. Next in value are goat and kid skins. These are brought from the East Indies, the Cape, North and South America, Mexico, and Asia Minor. The hides and skins of the seal, pig, walrus, elephant, rhinoceros, hippopotamus, porpoise, alligator, and

of the numerous species of deer, are all tanned for various purposes.

Leather consists of the hides and skins of animals, prepared by chemical and mechanical means in such a manner as to cause them to resist influences to which in their natural condition they are subject, and also to give them certain entirely new properties. Skins in their natural state readily putrefy; if dried they are horny and intractable. When converted into leather they resist putrefaction for almost any length of time. Tanning also secures suppleness, increases the strength to resist wear and tear, and renders impervious to, and unaltered by, the action of water. It is the *cutis* or true-skin only which is of use to the tanner; the epidermis and the hair have to be removed. As we have seen, the true-skin consists of a dense meshwork of fibrous tissue, in which are embedded blood-vessels, nerves, &c. It is the fibrous tissue only which makes leather. Boiled with water this tissue forms gelatine or glue; long treatment with tannic acid, or some other substances, converts it into leather. (For manufacture of leather, see Lesson XXXIII., Part II.

In the year 1883 there were imported into this country 634,116 cwt. of dry hides, valued at £2,250,000, chiefly from India, South Africa, and the countries of Europe. Also 562,733 cwt. of wet hides, valued at £1,500,000, chiefly from South America, Australia, South Africa, and the countries of Europe. Of sheep-skins upwards of 8,000,000 were imported, valued at £1,000,000; and of goat-skins, 4,500,000, valued at about £450,000. The sheep-skins were brought in greatest numbers from Australia, South Africa, South America, France, and Turkey; and the goat-skins from Bengal and South Africa.

3. FUR.—If we examine the hairy coverings of the cat we find two kinds of hair growing, intermingled side by side. One kind is short, soft, silky, curly, downy and *barbed* lengthwise. This is the *fur*. The other is longer, straight, *smooth*,

and comparatively rigid. This is the *over-hair.* Animals which live in cold countries are abundantly furnished with fur, while those which inhabit warm countries for the most part have short dry hairs. It is in the coldest countries that the most beautiful fur-skins are found. On the living animal the over-hair keeps the fur-filaments apart, prevents their tendency to felt, and protects them from injury; the double coat forming a beautiful provision for securing to the animal immunity from cold and storm.

Fig. 92.—Fur and Over-hair.

"Pelts," or fur-skins, are used either for *felting* purposes, or as *fancy skins* for articles of clothing or ornament. For the latter purpose the fur and over-hair, or the fur alone, is allowed to remain on the pelt. In most cases the over-hair is "the pride and beauty of the pelt, and makes its chief value with the furrier." In seal-skins for ladies' jackets, &c., the over-hair is usually removed. "The skin, after being washed, cleansed of grease, &c., is laid flat on the stretch, flesh side up; a flat knife is then passed across the flesh substance, thinning it to a very considerable extent. In doing this the blade severs the roots of the long strong hairs which penetrate the skin deeper than does the soft delicate under-fur. The rough hairs are thus got rid of while the fur retains its hold. A variety of subsidiary manipulations, in which the *pelt* is softened and preserved, are next gone through. The fur next undergoes a process of dyeing, which produces a deep uniform tint, and causes the filaments to lose their natural curly character. If we look at a lady's seal-skin jacket we at once observe its rich brown colour, and the velvety softness and denseness of the fine

hairs composing it. If this be compared with the coarse, hard, or salted dry seal-skin as imported; or, still better, with the coat of the living fur-seals, one is struck with the vast difference between them, and wonders how the coarse, oily-looking, close-pressed hair on the live animal can ever be transformed into such a rich-looking and costly garment."* For the second purpose, that of felting, the fur is removed from the pelt. After slight preparation by the aid of hot water, the fibres mutually interlace, under pressure, into a compact textile fabric called *felt*. The best fur for felting is that of the hare, rabbit, and beaver.

Some of the *fancy furs* are of great value, because of their great beauty and scarcity. The value depends on weight, pliability, elegance of texture, delicacy of shade, and fineness of over-hair. A choice specimen of the sea-otter has been sold for £100, and a fine silver fox skin will sometimes fetch £40. The yearly collection of fur-skins alone thoughout the world has been estimated at over 30,000,000, not including those used for felting purposes. The squirrel ranks first, as many as 6,000,000 animals being yearly slaughtered for the sake of their skins. Siberia yields the main supply of skins.

Rabbit-skins rank first for felting purposes. They are chiefly used for the manufacture of felt hats, and an immense trade is at present carried on throughout Europe in them, the statistics of which may be approximately set down thus: France heads the list with an annual production of 80,000,000 skins. Next comes England, with a yearly total of from 25,000,000 to 30,000,000. Belgium produces about 15,000,000, almost entirely of domestic breed. In Austria and Hungary about 12,000,000 are collected, but these are chiefly retained for home manufacture; 4,000,000 are turned out in North Germany; while Russia, Sweden, and Norway are responsible for but

* Cassell's "Natural History."

2,000,000. The English trade has developed very greatly of late years, and now amounts to at least £200,000 annually. The superiority of French rabbit-skins over any other lies not only in quantity, but in quality also. No others can compare with them, and large quantities are exported to both England and Belgium. Of late years the Australian colonies have been sending vast quantities to the market; indeed, in 1882 the number rose to 14,000,000, of an aggregate value of £126,000. Paris is the great centre for the preparation of the skins, and from thence dealers dispatch agents all over Europe. The various processes by which the fur is prepared for the manufacture of felt hats are most interesting, but even a cursory description of them would be too lengthy for us to give here. In yield of skins the hare follows next in number after the rabbit, and then the coypus,* musk-rat, cat, and seal.

In the year 1883 upwards of 600,000 undressed seal-skins were imported from various countries, chiefly from British North America, Norway, and the United States. Of other pelts 28,000,000 were received, chiefly from Australia, the United States, and various European countries.

4. Wool.—Wool is softer than the more common hair, and the filaments have a wavy character. Examined under a microscope, they are seen to be covered with scales which overlap each other. These scales are attached only at their bases to the cylindrical hairs, and wherever a bend occurs in the fibre the scales are seen to project. If the filaments be placed in reversed directions, the base of one towards the point of another, and pressed close together and pulled, it is clear that the scales will interlock. On this fact depends everything of importance connected with the woollen and worsted manufacture. In short-fibred, or, as it is called,

* A rodent, much resembling a beaver. It lives on the shores of the rivers and lakes of South America. In the fur-trade the skin is known under the name of "nutria," signifying otter.

short-stapled, wool, the fibres are more wavy and the scales are more numerous and distinct. This wool is best suited for the manufacture of "*broad-cloth*," while the long-stapled wool is woven into such *worsted* fabrics as alpacas, poplins, &c. The principal process in the preparation of woollen yarn for weaving, consists in combing or carding the wool so as to lay the fibres side by side, the bases of some being in contiguity with the tips of others. In spinning the thread the special use of the scales is seen, they interlock and prevent the thread from untwisting. If we take any hair which has not the special properties of wool we may twist it as much as we like, but owing to its elasticity and want of the projecting scales, it will not retain its twisted form. It is owing to the presence of these scales that wool, like fur, is a suitable material for felting. About 223,000 tons of imported sheep and lambs' wool are used every year in our woollen manufacture, in addition to the produce of our own country. Of this, about two-thirds is brought from Australia and New Zealand. The next largest supplies come from South Africa, Bombay, and Russia. In addition, about 6,000 tons of goats' hair or wool are imported, chiefly from Turkey and South Africa, and about 600 tons of the wool from the alpaca, vicuna, and llama from South America.

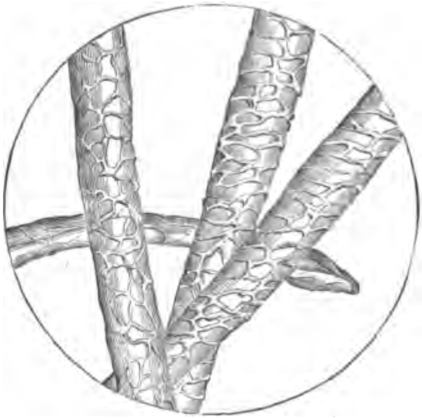
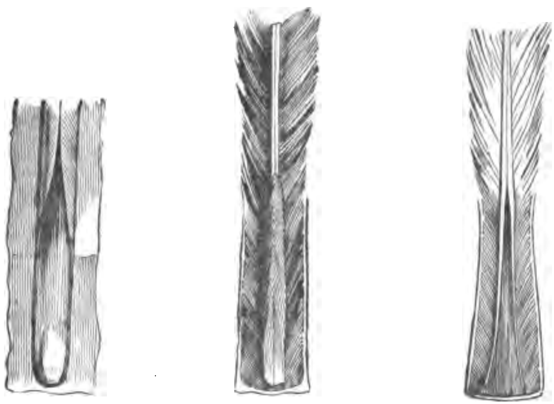


Fig. 93.—Fibres of Wool magnified, showing Scales.

5. Feathers.—The beautiful covering of birds which we call feathers is, like hair and wool and fur, but a develop-

ment of the epidermis. Feathers differ in their minute construction in particular birds, as also in colour, size, shape, and arrangement, according to their position on the animal. We may roughly classify them as *quill feathers*, *clothing feathers*, and *down*. The quill feathers are mainly concerned in flight; the covering feathers and the down constitute warm coverings to preserve the high temperature of the body. Feathers have the following parts in common:— *a*. A *tube*, or *barrel*, or *quill*—a hollow cylinder, partly em-



(*a*) Tube. (*b*) Shaft. (*c*) Web.

Fig. 94.—Parts of Feather.

bedded in the sac of the skin. *b*. The *stem*, or *shaft*, a continuation of the quill, composed internally of soft, compact, but elastic pith, having the buoyancy of cork. *c*. The *web*. From the shaft on either side spring a number of thin plates, at an angle more or less acute with the stem, arranged with their flat sides towards each other; and again from these plates, or *barbs*, spring other minute plates similarly arranged, called *barbules*. This is the *web*. The barbules interlock, and so retain the barbs in their proper position.

In some feathers the shaft is fine and tapering, and the barbs and barbules are long and loose, forming the light and graceful plumule as seen on the ostrich, emu, and some other birds. For commercial purposes feathers are classified as *ornamental*, *common*, and *down*. Many of the ornamental feathers, such as those of the ostrich, the humming-birds, birds of paradise, &c., are very brilliant and beautiful, and fetch high prices. In the year 1883 considerably more than half a million pounds of ornamental feathers were imported, having a value of upwards of two millions sterling. They were brought chiefly from the Cape (nearly one-half), the East Indies, and France and Holland. The feathers imported from France and Holland are the produce of their colonies. Of feathers for beds, pillows, &c., nearly 2,000 tons are imported. The beautiful soft, fluffy, light, and warm material known as "eider-down," is supplied by the eider duck. The principal home of this bird is on the bleak and frozen coasts of Northern Europe, and it has many breeding places on the rocky cliffs of the Outer Hebrides, and other islands off the coast of Scotland. The birds pluck the fine feathers from their breasts to line their nests. The owners of the breeding places abstract a portion of both down and eggs, following which the birds provide a fresh supply. A portion of the down and eggs are again taken a second, and a third time. The third supply of down is usually supplied by the male bird.

6. Hair, Bristles, &c.—Every part of the coverings of the common domestic animals is utilised in some way or other. The hair removed from the skins of cattle is used for mixing with the mortar used on ceilings; the hair from the manes and tails of horses is used for stuffing chairs and sofas, and for weaving into a kind of rough cloth; the parts of the hides and skins rejected by the tanner are boiled down to make glue; the horns of cows and oxen are made into combs and many other articles of utility; and hog

bristles are used in the manufacture of brushes. 1,200 tons of bristles, 3,000 tons of cow and ox hair, 800 tons of horse hair, and 6,000 tons of horns and hoofs were imported from various countries for manufacturing purposes in the year 1883.

Attention was directed in the last chapter to the shelly coverings of the articulata, and to the mantles and shells of the mollusca. Many of the animals still lower in the zoological scale make for themselves houses of stone, which have been and are still most important agents in the economy of Nature.*

CHAPTER XXVII.

THE BONY SKELETON AND ITS MODIFICATIONS.

The complete skeleton of a vertebrate animal may be considered to consist of an *essential* part—the *vertebral column;* and of various *appendages,* such as *ribs* and *limbs.*

The vertebral column is of course always present. Its main office is to protect the brain and spinal cord from injury; but it likewise serves as attachments for the appendages—when present—and as a support to the muscular system. The pieces of the vertebral column vary considerably in number and development; but the appendages, according to the varied and distinct purposes for which they are designed, present an almost endless diversity of form. In some of the vertebrates one or other, or all, of these appendages may be wanting.

Without pretending to enter into a consideration of the precise details of the structure of the skeleton, it is necessary for the proper understanding and appreciation of the various

* See Lesson XLVII., Part II.

and beautiful adaptations of structure to habit, to have a

Fig. 95.—Skeleton of Gorilla.

general acquaintance with the position and uses of the vari-

ous parts. We may take the human skeleton as a basis for comparison. The head consists of the *skull*, or *cranium*, and the *face*. The skull is a bony case formed by the union of *eight* bones, in which the brain is lodged and protected. In its base there are openings for the nerves which pass from the brain; and for the admission of blood-vessels which nourish the brain. The face is built up of *fourteen* bones, all of which, with the exception of the lower jaw, are united firmly to each other and to the skull. They enclose five cavities for the lodgment and protection of the organs of sense, viz., *sight* (two cavities), *smell* (a double cavity), and *taste*.

The vertebral or spinal column consists of *thirty-three* small bones, called vertebræ.* They are joined to each other by pads of cartilage, which provide for a certain amount of motion, and springiness. *Seven* of these bones form the neck † vertebræ; *twelve* the back,† and *five* the loin † vertebræ. Below these are *five*, which, though separate in the young, are united to form one bone—the *sacrum*—in the adult, and then *four* others, also united in the adult to form one bone, the *coccyx*. The first of the neck vertebræ, called the *atlas*, is more movable than the rest. The skull rests on this bone in such a manner that the head is free to *nod* backwards and forwards. The atlas itself turns on a projection from the next bone—the *axis*—as on a pivot, permitting the rotatory movement of the head. The dorsal or back vertebræ are those to which the ribs are attached. In man there are twelve pairs of ribs, which curve round and enclose the chest. Seven pairs—the *true* ribs—are joined by cartilage to the *sternum* or breast-bone; three pairs—the *false* ribs—are joined to each other and to the seventh pair in a similar manner, and the remaining two pairs are free, and are called floating ribs.

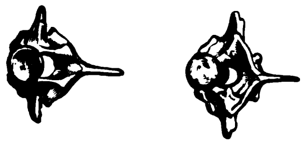
The two pairs of appendages, called in men *arms* and *legs*, are more or less closely connected with the central frame-

* From *verto*, to turn. † Cervical, dorsal, lumbar.

work by means of other bones and ligaments. The connecting link of the arms consists of the flat *blade-bone*, and the cylindrical *collar*-bone. The connecting bones of the legs are attached to the sacrum. The bones of the arms and legs are joined to each other and to the connecting links by ball-and-socket and hinge joints; and they form, with the assistance of the muscles attached to them, a series of beautiful natural levers. In number, structure, and position, the bones of the superior and inferior members are somewhat analogous. (See Fig. 95.)

It will be impossible to do more than glance at a few of the many variations in the structure of the bony skeleton of vertebrate animals. It is a curious fact that the number of neck vertebræ is the same in all mammals. The long-necked giraffe has only seven, while the elephant and the whale—animals which seem to have no neck at all—have also seven, although of course they are very thin. Birds have a larger number of neck vertebræ, the graceful swan having as many as twenty-three. The tortoises and lizards possess neck vertebræ, but in snakes and fishes they are wanting. Dorsal vertebræ have been defined to be those which carry ribs. Most mammals have more ribs than man. The elephant has twenty rib-supporting vertebræ. But it is among the snakes and fishes we must look for an enormous development in this respect. The python has nearly three hundred pairs of ribs, and in this and other members of the snake tribe, where arms and legs are absent, those ribs become organs of locomotion. They are connected on the one side with the vertebræ by ball-and-socket joints, while the other ends are free, that is, they are not joined to any sternum. They are, however, connected by muscles with the scales on the lower surface of the body, and it is by the action of these muscles on the ribs and scales that the snake is able to crawl. The animal progresses, so to speak, on the ends of its movable ribs, just as a caterpillar walks on its many legs.

No members of the fish tribe, and but few of the reptiles, have either lumbar or sacral vertebræ, but the bones of the tail become in some groups very numerous. Thus the python and the conger-eel each have 102, while the shark has 270.



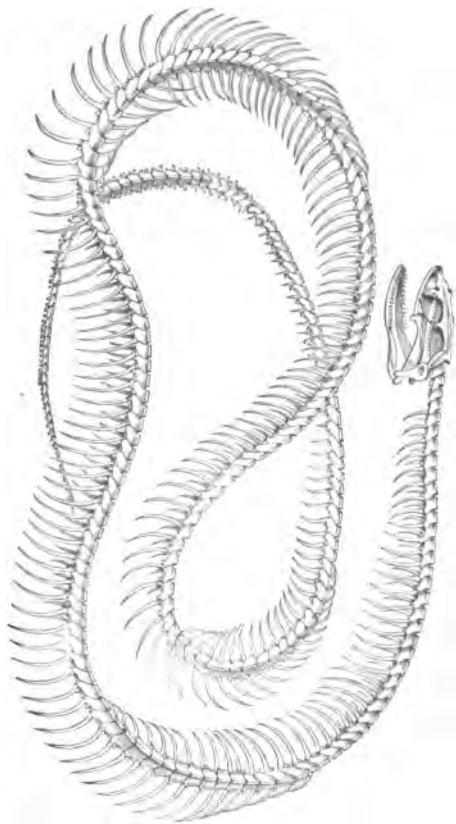


Fig. 96.—Skeleton of Snake. Vertebræ showing Ball and Socket.

In man and in mammals generally, the vertebræ are joined by pads of cartilage; but in the snakes and fishes a different plan is adopted. In the snake each vertebra has a rounded projection in front, and a hollow, like a cup, behind, and the "ball" of the one bone fits into the "socket" of the other, forming a chain of bones characterized by great flexibility and strength. Fishes are buoyed up and supported by the element in

which they live, and require flexibility rather than strength in their bony framework. In this class therefore the vertebræ present cups or sockets on both sides, and the rim of the socket of one bone fits close to the rim of the socket of the next bone. A hollow sphere is thus formed, and this encloses a bag containing a fluid over which the concave surfaces of the vertebræ freely play. A chain of bones is thus formed yielding extreme flexibility, but less strength than the ball-and-socket series of the snakes.

The vast majority of the vertebrate animals possess two pairs of limbs, corresponding to the arms and legs of man. They are present in all mammals, except that the hinder pair is wanting in the whale tribe. Birds invariably have both pairs. Of the reptiles, the crocodiles, tortoises, and lizards have both pairs; snakes have neither; while frogs and toads, possessing none in their young state, develop both pairs as they take on the adult form.

The primary object of the limbs is locomotion, and in no part of animated nature is beauty and simplicity of design more manifest than in the adaptation of the structure of the limbs to the different modes of progression, whether walking, running or leaping on the ground, climbing and swinging in the trees, flying in the air, swimming on or beneath the surface of the water, or burrowing and tunnelling in the earth. The variations depend less on the number and arrangement of the bones, than on the special development of one or more to suit special purposes.

Monkeys find their home among the leafy branches of great forest trees, and they swing and jump from bough to bough with wonderful alacrity. Now a foot, like that of man, would not be a very serviceable member for clasping and climbing; but by a simple change of position in the bones, particularly in those which in man constitute the skeleton of the great toe, a hand is formed; inferior, it is true, to the

hand of man for performing delicate operations, but possessing great power of grasping.

Bats capture their insect prey in the air, and they must

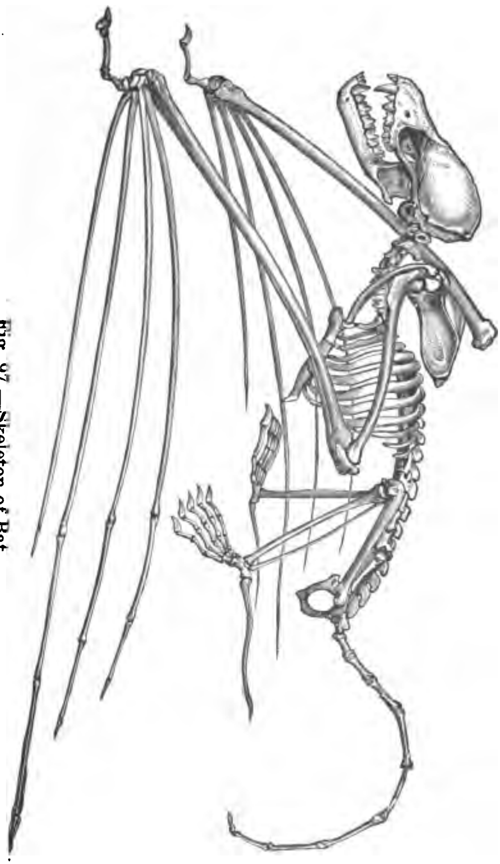


Fig. 97.—Skeleton of Bat.

have wings for flight. By a modification of the size and form of the bones of the fore limbs, a framework for the wings is formed. The metacarpals are greatly lengthened, and to a less extent the phalanges, so that the middle

finger becomes longer than the whole body. The thumb-bones are small, and the thumb ends in a sharp curved claw. The hind limbs are of ordinary size, and are armed with claws.

There is another interesting modification in the skeleton of the bat. This we find in the bones of the lower arm. These in man and in most of the lower animals are two in number (see Fig. 95), and they are connected at the elbow and the wrist in such a manner as to permit of the rotatory motion by which the palm of the hand may be turned upwards or downwards. But in the bat such a power of motion would be a source of weakness rather than of strength, unless the muscles were made disproportionately powerful, for the pressure of the atmosphere against the wing would turn it sideways at every stroke, and thus cause it to cleave through the air instead of beating against it.

Fig. 98.—Skeleton of Cat.

One bone, therefore, of the forearm—the *ulna*—is not developed, or is present only in a very rudimentary form attached to the *radius* near the elbow, so that a twisting motion of the arm or wing is impossible.

The bones of the legs and feet of the cat and dog families

and their allies correspond in number and position almost exactly with those of the foot of man; but the *carpal* and *metacarpal* bones are set on the *radius* and *ulna*, and the *tarsal* and *metatarsal* on the *tibia* and *fibula*, in such a way that they practically form a portion of the legs; they are lifted well above the ground, and the animals walk with an elegant and silent tread on the very tips of their toes. That which looks like the knee of a cat or dog is really the *wrist*, and that which appears to be a backward-turned knee in the hind leg is really the *heel;* the true elbow and knee are close to the body and almost hidden by the skin. The only carnivorous animals which walk with the sole of the foot on the ground are the bear, racoon, glutton, and beaver families.

Fig. 99.—Skeleton of Seal.

In the limbs of the sea-lions and seals all the ordinary bones are present; but they are developed so as to form a strong internal framework, which, with the covering hard membrane, form efficient paddles for swimming. The arm-bones are short while the finger-bones are long, so that the fore-flippers show little more than broad hands distinct from the body. In the hind limbs the

thigh-bone is short, while the leg-bone and the phalanges are long In the common seal the legs are directed backwards almost in a line with the body, and are closely bound to the tail by a membrane as far as the heel. In the whale tribe the fore limbs resemble those of the seals, while the hind limbs are wanting. Most of the rodents have the hind legs longer and more powerful than the fore legs, and the latter, serving as they often do in a certain degree as hands, have the ulna and radius distinct. They usually have *five* toes, but this number is reduced to *four*, and even to *three*, on the hind feet.

Our common domestic animals, the horse, ass, cow, sheep, and pig, as also the rhinoceros, hippopotamus, and tapir, walk on one or more toes. The leg of the horse is a beautiful adaptation for the purpose of strength, speed, and springiness. The upper and lower arms and leg bones correspond with those of most other mammals, except that the ulna and the tibia are absent, but the bones corresponding to our hands and feet are changed almost out of recognition. The bones of the knee of the fore leg and of the backward-turned knee of the hind leg, correspond to those of the wrist and ankle. If we except two small bones, called *splint* bones, only one metacarpal and one metatarsal bone is present, with three phalanges at the end of each. The metacarpal and metatarsal (cannon) bones are elongated and strengthened, and set upright on the first of the phalanges. The last of the phalanges is partly enclosed by a hoof which corresponds to the finger nail.

Fig. 100.—Foot of Horse.

The rhinoceros and tapir have each *three* toes; the hippo-

potamus, the pig, and the ruminants* generally, have *four* toes.

Fashioned on the same principle as that of mammals, the skeleton of birds differs materially in some respects. In the first place the bones of the limbs instead of being solid, or filled with marrow, are hollow; and for these reasons, as supports for the powerful muscles they must be strong, and for the attachment of these muscles they must be large; while at the same time they must not be too heavy, or flight would be impossible. In the second place the bones of the fore limbs are modified to suit the requirements of a wing instead of a hand or leg. The bones of the forearm are lengthened, the increase in length bearing relation to the power of flight, while the hand is reduced to a single piece for the support of the large feathers of the wing. A rudimentary thumb and the vestiges of a third finger are, however, present. In the hind limbs the thigh-bone is short and directed forwards, the leg-bone is longer and composed of but one strong bone, while the ankle and foot-bones are represented by one bone, which practically forms a lower leg-bone. It is the length

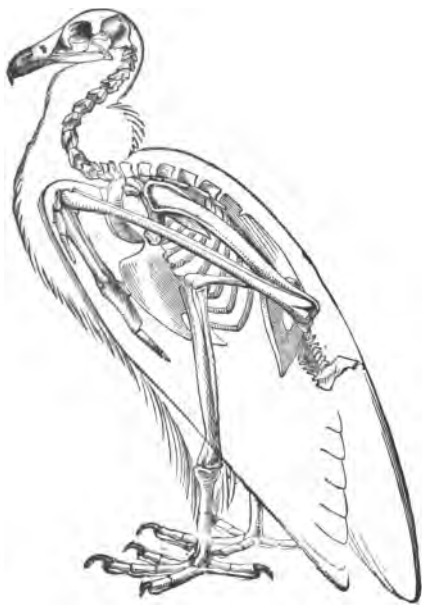


Fig. 101.—Skeleton of Vulture.

* In the sheep and ox two are mere rudiments, and in the camel and giraffe *two* toes only are present.

of this bone which determines the *height* of the bird when standing.

In the tortoises and turtles the skeleton undergoes a peculiar modification, to assist in the formation of a great plate, called the *carapace*, which covers the animal as with an umbrella. This carapace is formed of the vertebral column,

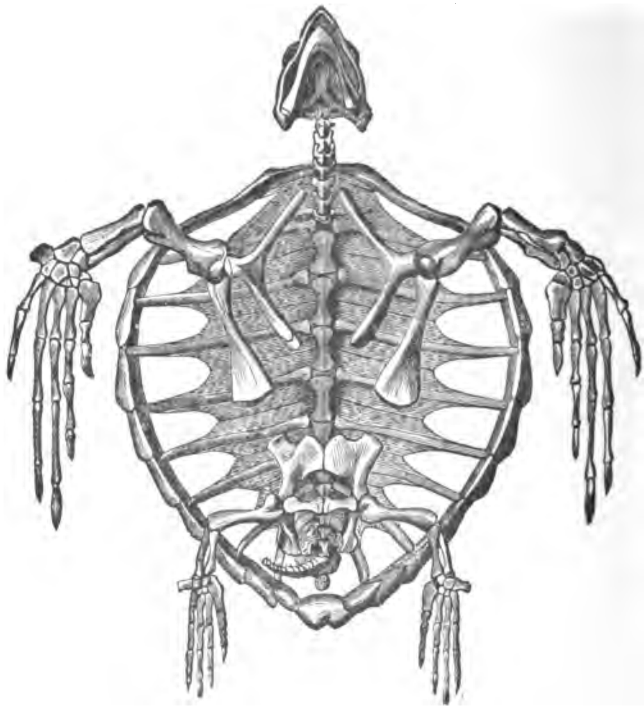


Fig. 102.—Skeleton of Turtle.

the ribs, and certain bony plates in the skin, all grown together (see Fig. 102). It may be covered with a leathery skin, or with a horn-like substance called tortoise-shell. The under plate, or plastron, is not formed by the bones of the skeleton, but by dermal or skin bones. The bones of the carapace

and plastron are consolidated and motionless; not so the neck, tail, and limb-bones. The latter are as free as in the typical mammal, and all the chief bones are present.

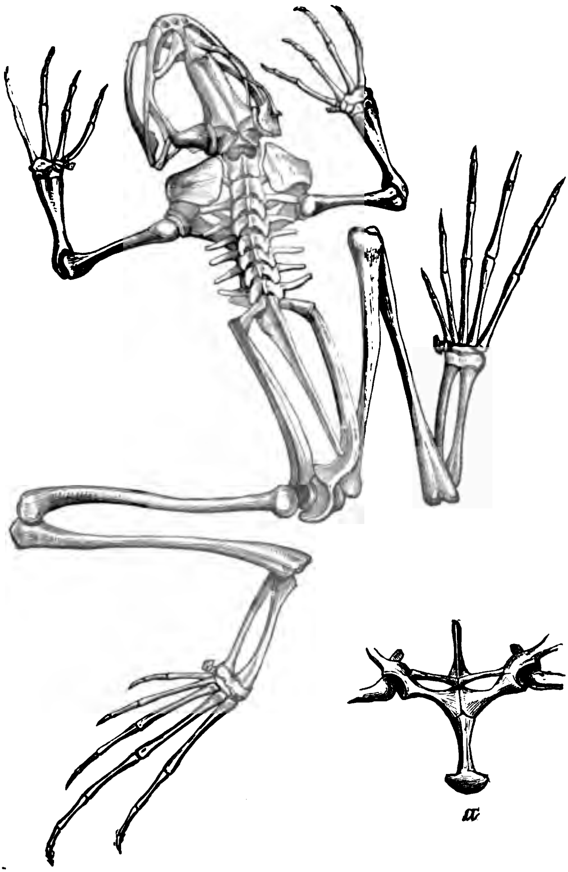


Fig. 103.—Skeleton of Frog.

The skeleton of the frog also shows some interesting modifications. The bones which connect the limbs with the vertebral column are large and strong; and so are the "transverse pro-

cesses" of the vertebræ. The latter, in some measure, compensate for the absent ribs. As the fore limbs are less used by the animal than the hind limbs, the bones are shorter and smaller. In the fore limbs the radius and ulna, and in the hind limbs the tibia and fibula, form but one bone. There are *six* wrist and *six* ankle bones; but two of the latter are very much elongated, and have all the appearance of the usual double leg-bones. In the hind legs the metatarsal bones and phalanges are very long. They support the swimming-web.

The *pectoral*, or breast fins of fishes, represent the fore-limbs of the higher vertebrates; and the *ventral*, or belly-fins, represent the hind legs. Sometimes one pair, and occasionally both, are absent.

CHAPTER XXVIII.

TEETH—THEIR VARIETIES AND USES.

The food of most of the mammals requires to be cut, or crushed, or ground, before swallowing. For this purpose teeth are provided. They are fixed partly in the upper jaw and partly in the lower, on either side, and in front of each. The lower jaw only is movable. The number of teeth, the kind of teeth, and the particular motion of the lower jaw depend on the kind of food on which the owner feeds.

Our own teeth may be taken as the best example with which to compare the teeth of the lower animals. They are of *three* kinds adapted to as many different purposes. First, there are *four* chisel-shaped teeth in front of each jaw, adapted for cutting like a pair of shears; these are named *incisors*, or *cutting* teeth. On either side of the incisors in both jaws we find *one* long conical tooth. In many animals,

particularly in those which live on flesh, these teeth grow much longer than the others, and become very prominent. For instance, they are prominent in the dog; and it is from their resemblance to these teeth of the dog that ours are called *canine*, or dog-like teeth. There are of course *four* canine teeth. They are not adapted for cutting the food, but rather for seizing and *tearing* asunder. Behind the canines we find teeth of the third kind, having large, irregular, flattened surfaces adapted for *grinding* the food. These are called *molars*, or mill-like teeth. When all are present there are *ten* in either jaw, *five* on each side. In the adult man or woman therefore, when the teeth are perfect, they number *thirty-two—eight* incisors, *four* canines, and *twenty* molars. Each tooth consists of the *root* or *fang*, the *neck*, and the *crown*. The crown is the part seen above the gums.

Teeth are made of a hard bony substance named *dentine;* but the crown of the tooth is covered with a much harder substance still, called *enamel.* There is a small space in the centre of each tooth, and the walls of this chamber are covered with a membrane filled with nerves. When through accident or decay the dentine is destroyed, and this nervous membrane is exposed to the air, *tooth-ache* often follows.

We have already stated that the kind of teeth, and the motion of the lower jaw, vary according to the nature of the food. So exact is this correspondence that it is often possible to determine, by the simple inspection of the teeth of an animal, not only the nature of its food, but also the general structure of its body, and even its ordinary habits. The teeth of the monkey tribe resemble those of man, except that usually the canine teeth are much larger. They are admirably adapted for biting, and tearing, and grinding the vegetable food, hard or soft, on which the animals feed, and fortunately for their owners, they never decay.

It is a curious fact that the monkeys of the New World

have *four* more molar teeth than the monkeys of the Old World.

Animals of the cat-family, which feed exclusively on flesh, have the incisors small; but the canines, which seize and hold their prey, and which penetrate and tear asunder the flesh, are remarkably developed. Flesh food requires cutting and not grinding, hence the molars are compressed so as to form cutting edges which work against each other like the blades of a pair of scissors. The jaw, too, can only work up and down; it has no lateral motion like the jaw of the horse to adapt it for grinding.

Fig. 104.—Cat's Teeth.

The members of the dog-family are also flesh-eaters, but not exclusively, and so their teeth are modified accordingly. The scissor-like cutting-edges of the two back molars—upper and lower—have disappeared, and the teeth have become real "grinders." In the bear-family the teeth are again still further modified to suit the mixed flesh and vegetable diet. Four molars in each lower jaw and three in each upper, instead of having the sharp cutting character they have in the cat, have comparatively flat crowns, with slight elevations fitted for grinding. There is also a corresponding change in the movement of the jaw. It is no longer a hinge movement, but the jaw can be worked from side to side, and the bear can actually *grind* his food. In the aquatic carnivora—the seal-tribe—the dentition again changes to suit the habits of the animals. The teeth are specially formed for *seizing* and *holding* the slippery prey on which they feed; and for dividing the body of the fish they devour into large pieces. The peculiar scissor-like cutting molars of the land carnivora are replaced by teeth

either serrate, or *saw-like* in character, or somewhat flattened crowns with conical projections. In the walrus, while the lower jaw has neither incisors nor canines, the canines of the upper jaw—tusks, they are termed in this animal—are of great length and strength. They are sometimes as much as two feet in length, and weigh twelve or fifteen pounds. They are used by the animal for the purpose of procuring food. Part of its time is spent on the shore and in shoal water, and the tusks are used for digging up mussels and cockles and

Fig. 105.—Teeth of Seal.

other shell-fish. They also serve another purpose. When the animal wishes to get from the water on to the ice the tusks are dug into the ice with great force, and the body is hauled up. They are also used as powerful offensive weapons. Unlike any other teeth previously mentioned—which, when full-grown, cease to increase in size, these teeth grow continuously as they wear away.

The teeth of bats, again, vary in structure according to diet (see Fig. 97). By far the larger number of these little nocturnal animals feed on insects. These have small but

sharp-pointed teeth, adapted for crushing the hard envelopes of insects. Such teeth are of course unsuitable for mastication, and the jaws of the bat move up and down only, much like the jaws of the cat. The fruit-eating bats have small molar teeth with rounded projections adapted for grinding their food; while bats which get their food by sucking the blood of other animals have long and lancet-shaped canines for making incisions. The molars, having little or no work to do, are small and imperfectly developed.

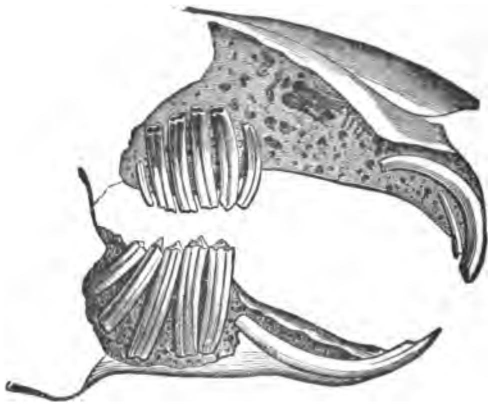


Fig. 106.—Jaws of Hare.

The teeth of the insectivora resemble the teeth of the insect-eating bats; the molars being similarly furnished with sharp points for crushing the hard envelopes of their insect prey.

One of the most remarkable examples of the adaptation of the structure of the teeth and the motion of the jaw to the habits of the animal, is seen in the vast group included under the name Rodentia. In these animals, as the name implies, the teeth are specially adapted for *gnawing*. They are of two kinds only—incisors and molars—and the number

of the former never exceeds two * in each jaw. The great incisors are constructed in a manner most efficient for their purpose. In the first place they require to be strong and to be kept constantly sharp, so that the animal may be able to cut through tough and hard vegetables. In the second place provision must be made to make good the loss attributable to constant attrition.

The teeth are composed of dentine coated along the front surface with a plate of hard enamel. By constant friction the substance of the teeth is worn away, but the softer dentine is worn away more rapidly than the harder enamel, hence the latter is left as a sharp projecting cutting edge. Chisels are constructed on this principle, a thin plate of steel laid along the front of a thicker layer of iron forming the cutting edge. But were no provision made for renewing their substance as fast as they are worn away, the teeth would soon become useless. So these teeth are formed constantly to grow and increase in length. As fast as they wear away above, they are pushed forward from the base. These teeth have no real roots, they are buried far in the jaw-bone, and their buried ends are hollow and filled with pulp, from which new dentine and enamel are being constantly formed. By this means as the teeth are worn away in gnawing, a fresh supply of tooth is being constantly pressed forward to supply its place. As the teeth are constantly growing we see how necessary it is they should be kept in constant use.

The gnawing animals have no canines in either jaw, and a considerable space separates the incisors from the molars. The latter vary in number and to some extent in form; but in most of the rodents the enamel is arranged in transverse plates which, wearing more slowly than the dentine, give to the surface of the teeth a *rasp-like* appearance; and curiously enough, the teeth are used very much in the same way as a

* In hares and rabbits two rudimentary incisors are found in the upper jaw behind the large teeth, but these never render effective service.

rasp is used. The lower jaw is so jointed to the upper that it has very little lateral motion; but, instead, a rasping motion forwards and backwards. This particular motion answers well for the reduction of hard substances, and in addition gives to the incisors a much greater power of gnawing.

In all ruminants, except the camel-tribe, incisor teeth are wanting in the upper jaw. The upper canines are more often absent than present, though in a few of the deer-tribe, such as the musk deer, they are enormously developed, projecting far down outside the lip. The molars are well-adapted for grinding; their surface shows crescent-shaped ridges formed by the projecting bands of enamel.

The full complement of teeth in the horse is 40, viz., 12 incisors, 4 canines, and 24 grinders. The canines are small (the upper are not present till old age in the female) and are placed at some distance from the cutting-teeth. A much larger space intervenes between the canines and the grinders. This space is called the *bar*, and receives the "bit."

The dentition in the elephant is very interesting and instructive. As in the rodents, incisors and molars are present. In the Indian elephant, which presents several points of difference from the African elephant, the males alone have well-developed incisors in the upper jaw; in African elephants both sexes are provided with them. These incisors, better known as tusks, grow to a very large size, sometimes reaching the weight of from 150 to 200 lbs., and project a considerable distance from the mouth. Like the incisors of the rodents, they grow from a pulp which is continually forming new tooth material, in this case named *ivory*. There are incisors in the lower jaw, but no canines in either. During the lifetime of the animal it may have as many as 24 molars, but there are never more than two in each jaw at the same time. "These teeth move forward into their working place in the jaw in regular succession, from behind forwards, each being pushed out by its successor as it is gradually

worn away. They present a gradual increase in size as they successively appear. The teeth are worn away not merely by the food on which the animal lives, but also by the particles of sand and grit entangled in the roots of herbs torn up for food, and their wear is compensated by the growth and development of the succeeding teeth. The molar or grinding teeth of the elephant are for the most part buried in the socket, and present little more than a surface for mastication above the gum. Each is composed of a number of transverse perpendicular plates, built up of a body of dentine, covered by a layer of enamel, and this again by a layer of cement, which fills the interstices between the plates and binds together the divisions into one solid mass. Each of these enamel plates, however, in the perfect tooth, is united at the base. The difference between the grinders of the Indian and African elephants is well marked. In the former, the transverse ridges of enamel are narrower, more undulating, and more numerous than in the African, in which latter species the ridges are less parallel, and enclose lozenge-shaped spaces."

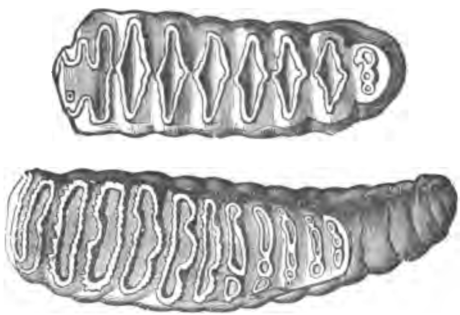


Fig. 107.—Teeth of Elephant.

The tusks of the wild boar are largely developed canines; but they grow in a manner precisely similar to the growing teeth of the rodents and the tusks of the elephants.

The teeth of the cetaceans vary considerably in the different species; but generally they are numerous, simple, sharp, and of a conical shape, suitable only for seizing and retaining their living prey. Two exceptions deserve special

notice. The first of these is the narwhal, or sea-unicorn. The male narwhal has one canine tooth of the upper jaw, occasionally both, developed into a long spiral tusk, projecting straight forward, sometimes five or six feet, in front of the head. The narwhal has no proper teeth. The other exception is that of the whalebone whale, whose upper jaws and palate are provided with plates of whalebone instead of teeth. These plates are composed of a horn-like material, similar to that of which our finger-nails are made; the free edges are split into fibres, and the fixed ends are embedded in the gums of the upper jaw, like the finger-nails are embedded in the flesh of the fingers. The plates grow continuously from the roots, and at first consist of a brush of hair-like bodies; these gradually lengthen, and at the same time the part near the root becomes the solid horny substance known as the blade. The transverse arrangement of the plates, several hundreds in number, with split and fringed inner and lower edges, causes the mouth, when open, to have the appearance of a great hairy archway. The purpose of this complicated arrangement of fringed plates is that of a sieve. The whale feeds on small creatures, and vast quantities are required to satisfy its hunger. The animal opens its huge mouth and takes in a quantity of water containing its minute marine food, and then, closing it, the water escapes, while the tiny prey is entangled in the hairy meshes.

Last among the mammals are the edentates or "toothless" animals—the ant-eaters, sloths, and armadilloes. These have neither incisors nor canines, and some have no molars; but most of them have a few of the latter kind, simple and conical in shape, but without the usual covering of enamel. Their food consists of soft-bodied insects, and, in the case of the sloth, of soft leaves and twigs, hence teeth are little needed.

Birds have no teeth. Reptiles and fish have many teeth; but generally they are of a much less complicated nature

than those of mammals, being simply conical and curved backwards for the purpose of preventing the escape of prey, rather than for cutting or grinding. But innumerable modifications occur. Thus the teeth of the deadly shark are flat and lancet-like, the cutting edges being notched like a saw; the front teeth of the flounder are flat grinding teeth; other fish have convex teeth, so numerous and so closely packed over a broad surface, as to resemble

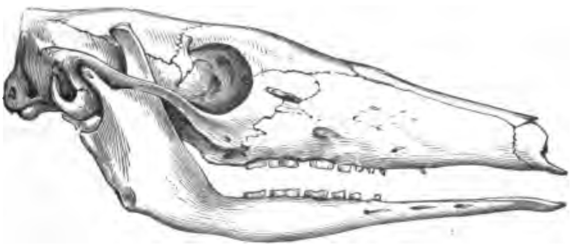


Fig. 108.—Skull of the Cape Ant-eater.

the paving-stones of a street; a few have teeth which resemble bristles, and these are set together like the hairs of a brush. The common perch has teeth still more slender, being so minute and numerous as to resemble the pile of velvet. The well-known pike is armed with teeth scarcely less formidable than the canines of a carnivorous mammal, while the sturgeon and a few other fish are entirely toothless.

CHAPTER XXIX.

TONGUES.

The Tongue is the special organ of *taste*; but the "unruly member" has other and no less important duties assigned to it. In man it is one of the chief instruments of speech. In

mammals, generally, it is the chief guide in the choice of food, and an important assistant in the act of mastication and in the process of deglutition. In a few of the mammals, and in some of the birds and reptiles, it is modified into an efficient organ of prehension.

The structure of the tongue differs but little in the mammalia. It is a fleshy organ covered with a *mucous membrane* or *skin*, and fastened at one end to the floor of the mouth. The mucous membrane is covered with little projections, called *papillæ*. Some of these papillæ are concerned with taste, others with more mechanical work. In the cat-tribe the latter are horny and pointed backwards. They serve as rasps to scrape off the smaller fragments of flesh from the bones. So large and sharp are they in the lion, that a stroke or two of the tongue would take the skin from a man's hand. Cats and dogs, and their relations, use the tongue for lapping liquids.

Fig. 109.—Cat's Tongue.

Animals which "chew the cud" have long tongues which aid in taking food into the mouth. In the case of cut grass, or hay, the tongue is the only organ used in gathering food. In cropping grass, or other growing herbage, the food is drawn into the mouth by the tongue and pressed by the lower incisors against the hard pad of the upper jaw, and then torn off with a jerk of the head. In the giraffe the tongue can be lengthened or shortened in a very curious way. This animal feeds on the leaves of trees which are gathered by the tongue, and this organ is so delicate that it can grasp and pluck a single leaf selected at will.

Other mammals have their tongues not only lengthened, but covered near the free end with a gummy substance, or even with hairs, to collect food. Thus, in some of the bats the long pencil-like tongue is set with recurved bristles, and

can be protruded to a considerable distance. These bats feed on soft fruits, and no doubt when the tongue is pressed into the soft pulp and withdrawn, the bristles retain a large quantity of the food. In the ant-eaters the long projectible tongue is covered with slimy saliva. Their favourite food is ants, and these they collect by pushing the tongue into holes they make with their claws in ant-hills. The tongue having made its entry is soon covered with the insects, which are held fast by the saliva, and carried into the mouth as the tongue is withdrawn.

Fig. 110.—Tongue of Fruit-bat.

The great ant-bear opens the ant-hills with his powerful claws, and then as the insects flock from all quarters to defend their dwelling, draws over them his long flexible tongue covered with glutinous saliva to which they consequently adhere. So quickly is the operation performed that it is said the animal can take two helpings of food in a second.

In many birds the tongue is covered with a horny substance, so that it can be of little use as an organ of taste. In other birds it is but slightly developed, and in the pelicans it is entirely wanting. In birds of prey it is broad and soft. In parrots the tongue is fleshy, and is used for holding solid substances against the upper beak, while the lower gives it another bite. The most unique tongue in the class of birds is that of the woodpecker. In this bird it is developed into a long thin organ adapted for the collection of insects from deep holes and crevices. It tapers to a slender horny point, the sides and upper surface of which are beset with bristles pointing backwards and moistened with a thick glutinous saliva. This bird can project and withdraw this tongue with marvellous rapidity.

In some of the larger reptiles the tongue is fleshy and covered with a thick rugged membrane sometimes beset with

Fig. 111.—Tongue of the Woodpecker.

pointed papillæ; but in general it is thin, dry, very protractile, and cleft towards the end. In two or three species of reptiles, however, the tongue is developed into a remarkable instrument for the capture of prey. In the curious chameleon it is worm-shaped, and can be thrust out to a length of several inches with singular rapidity and certainty. The tip is thickened and slightly

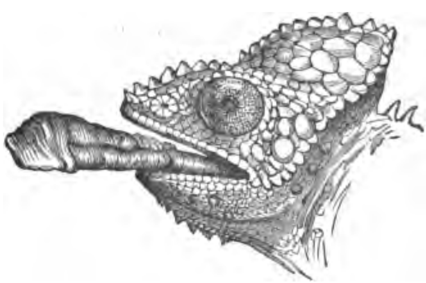


Fig. 112.—Tongue of Chameleon.

cup-shaped, and covered with a sticky secretion. The chameleon is very slow and measured in its general movements, but the tongue is very active. The animal does not chase its insect prey; but watches and waits until the insect comes within reach, when at first it slowly protrudes its tongue as if taking aim, and then darts it forward with lightning-like rapidity and unerring precision. The prey is held fast by the glutinous secretion and carried into the mouth. In the frog, again, the tongue plays the leading part in the capture of prey. The soft and fleshy tongue of this animal, and its ally the toad, is fixed on the front instead of on the back of the floor of the mouth. When in repose the free end is at the back of the mouth, but when the animal puts it out the tip reaches to a considerable distance outside the mouth. "When the frog sees an insect which he desires to catch, he approaches within striking distance, and then flips his tongue at the victim. As the tip is always anointed with a glutinous matter, something like treacle in consistence, the insect adheres to it and so is flung down the throat." The action of the tongue is so rapid that the eye can hardly follow it; something pink flashes from the frog's mouth, and the insect has vanished.

Fig. 113—Tongue of Frog.

Some of the invertebrate animals have wonderfully-constructed tongues. In the limpet, periwinkle, slug, and whelk, the tongue is a ribbon covered with rows of microscopic teeth forming a most efficient ribbon-saw. They are used for *scraping*, in the same way as a cat uses her tongue; or for *boring* through hard shells, and then "licking" out the contents.

CHAPTER XXX.

TAILS AND THEIR USES.

Tailless animals among the vertebrates are the exception. The man-like apes and a few of the rodents among mammals, and frogs and toads among reptiles, have no tail; but the vast majority can boast of a caudal* appendage. It may be but a mere rudiment, seemingly of little use to its owner; or it may form one of the most interesting and important organs of the body. It is useful as well as ornamental; its duties are numerous and varied. It may be an index of the feelings, an engine for locomotion, a rudder to guide, a weapon of offence, a covering for warmth, and even an umbrella to protect from the inclement weather.

Many of the monkeys of the new world—the howlers and spider monkeys—are provided with *prehensile* tails, by means of which they clasp and hang from the branches of trees, while their hands are at liberty for other purposes. These tails must of course be very muscular and strong; but, in addition, the under surface near the tip—a part destitute of hair—is endowed with an exquisitely sensitive sense of touch. These animals can therefore with their tails feel here and there for anything to catch hold of without looking, as they make their way from branch to branch. As we have already seen, the bony framework of the tail is but a continuation of the vertebral column, but to yield the necessary flexibility the vertebræ are very numerous. These tail-bones exhibit a striking example of the adaptation of structure to habit. To sustain the weight of the animal the tail must embrace the support very closely, and the nerves and blood-vessels would be liable to severe pressure; to prevent this there are two curious projections from the lower

* *Cauda*, a tail.

part of the body of each vertebra (shaped together like the letter V), between which these organs pass without being pressed upon. So perfect is this tail, and so wonderful in its movements, that it has with good reason been called a fifth hand. It clasps so firmly that, when shot dead, the animal has been known to hang for several hours by its tail before falling to the ground.

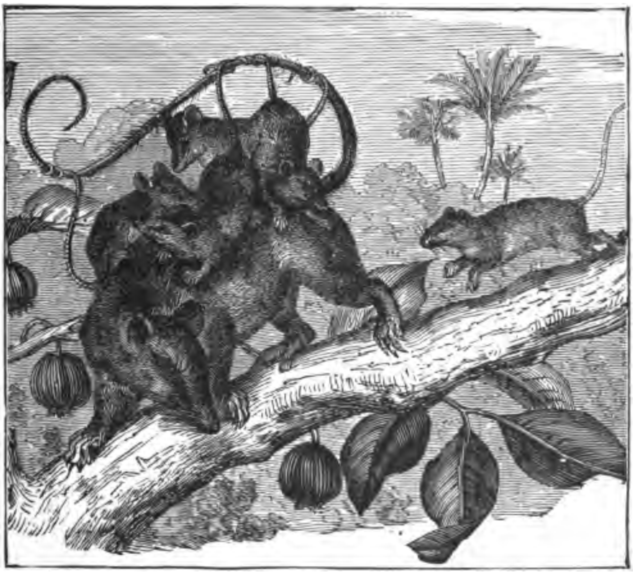


Fig. 114.—Prehensile Tails. Opossum and Young.

A few other animals besides the monkeys have prehensile tails. The smallest of them is the active little harvest mouse. With the aid of its long slender tail this animal climbs up the stalks of corn, and other grasses, as nimbly as a monkey climbs among the branches of trees. In descending it twists its tail round the stalk, and slides gracefully to the ground. The opossums, and some of their

relations, many of which are natives of America, and others of Australia, are also gifted with prehensile tails. In some of the American species the tail is put to a very curious use. The young are carried on the back of their mother, and with their tails they cling on to her tail, which is curved over her back for the purpose.

Many tails again are bushy, and covered with warm hair and fur. The fortunate possessors of such tails, as they lie down, curl them round to the front and cover their fore-paws and noses for the sake of warmth. The squirrels, the fox, the dormouse, the lemurs, and many other animals make use of their tails in this way. The long bushy tail of the so-called flying-squirrel serves as a sort of rudder to guide the animal as it glides through the air in its long jumps. The feathery tails of birds serve a similar purpose.

The tails of some animals serve to give expression to their feelings. When a dog approaches another dog, or a man in a hostile frame of mind, its tail is held erect and quite rigid, but when in a friendly spirit it is lowered and wagged from side to side. Fear is shown by a further depression of the tail, and the dog slouches away with "its tail between its legs." The cat, in anger, lashes her tail from side to side; but when she runs to meet her mistress, or to take her food, her tail is held quite stiff and perpendicularly upwards.

The cow and the horse have but a scant covering of hair on their skins, and they are consequently liable to attack from insects which pierce the skin and suck the blood, so nature provides these animals with long tails which act as "fly-flippers."

"The great ant-bear makes neither nest nor burrow, its ample tail serving as its sole protection against the inclemency of the weather." "He is slothful and solitary, and the greater part of his life is spent in sleeping. When about to sleep he lies on one side, conceals his long snout in the fur of his breast, locks the fore and hind claws into one

another so as to cover the head and belly, and turns his long bushy tail over the body, covering the whole as with an umbrella."

Fig. 115.—Kangaroo Rat.

The kangaroo uses its tail as a fifth leg. When resting and feeding it supports itself on its hind legs and its tail.

The jerboa-kangaroo has a prehensile tail, and makes use of it in collecting grasses with which it constructs its nest. "As may be easily imagined the appearance of this kangaroo

when leaping towards its nest, with its tail loaded with grasses, is exceedingly grotesque and amusing."

All the vertebrate animals which spend the whole of their lives in the water, as well as some others which spend a portion of their time on land, use their tails as sculls and rudders; sculls for propelling the body forward, just as a boatman propels his boat by a single oar worked from the stern of his boat; and rudders to turn the body so that it may move in any required direction. On land the crocodile uses its tail as a weapon of destruction. It stupifies its victim with a blow from its tail, and then drags it into the river, where it is soon drowned.

CHAPTER XXXI.

THE POSITIONS AND FUNCTIONS OF THE PRINCIPAL INTERNAL ORGANS OF ANIMALS.

We have now to consider the positions and functions of the principal internal organs of animals. Taking the human form as the model for comparison, we may refer to the *brain*, the *heart*, the *lungs*, the *stomach* and *intestines*, and the *liver* as the chief organs.

The brain is contained in a box of hard bone called the skull, or cranium. The heart and the lungs are the chief organs of the chest or thorax, while the organs concerned in the digestion of food are enclosed in the lower half of the trunk called the abdomen. The thorax is separated from the abdomen by a convex muscular sheet, the *diaphragm*.

The NERVOUS SYSTEM consists of the *brain* and *spinal cord*, and the *nerves* connected therewith which traverse every part of the body. The brain consists of a mass of soft substance, a white internal portion and an exterior layer of grey matter. The latter is arranged in folds in such a way that it looks like a handkerchief crumpled up. The spinal cord is con-

tained in the canal of the vertebral column. It passes through an opening in the base of the skull, and is thus connected with the brain. Like the brain it consists of white and grey matter, but here the grey matter forms the internal portion. The nerves are small white cords which carry messages *to and from* the brain. We have special organs of sight, smell, taste, and hearing, and a general sense of touch in the skin, and one set of nerves carries messages *to* the brain from these organs. A second set of nerves carries messages *from* the brain to set the muscles in action. In addition to the nervous system of the brain and the spinal cord there is another nervous system consisting of small masses of nerve matter, called *ganglia*, lying principally at the sides and in front of the spinal column. The ganglia are connected with each other and with the spinal cord by connecting nerves, and they send off nerves which form great networks upon the heart and about the digestive organs.

Fig. 116.—Brain and Spinal Cord.

RESPIRATION.—The special purpose of the lungs is to bring the blood into close contact with the air, so that an interchange may take place. The lungs consist of a number of tubes dividing and subdividing from the main tube—the "windpipe"—until finally each little tube ends in a sac or pouch. These tiny sacs are covered with a membrane full of blood-vessels; and it is in these sacs that the aeration of the blood takes place. Oxygen from the air is taken in through the thin walls of the blood-vessels, and carbonic acid gas and vapour of water are given off. The carbonic acid gas and the water-vapour are the products of the oxidation or combustion of our "fuel-food" and the "waste-

tissues." This oxidation produces and sustains the natural heat of the body. A considerable quantity of air is necessary to maintain a high body temperature.

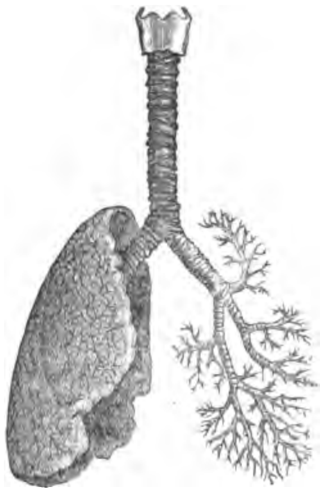


Fig. 117.—Wind-Pipe and Air-Tubes —one side covered by Lung.

CIRCULATION.—The heart is the organ of circulation—that is, it is the motive power which carries the blood round and round in the body; the tubes which carry the blood from the heart are named *arteries*, those which take the blood to the heart are called *veins*. Between the small arteries and the small veins, and connecting them, are the minute hair-like tubes—the *capillaries*. These capillaries go everywhere in the body, through and through the muscles, over and within the brain and spinal cord, through tiny holes in the bones to their marrow, to the root of every tooth, and to the base of every hair. The skin is a network of capillaries; it is impossible to insert the point of a needle anywhere without penetrating some of them So the blood flows everywhere, and in its ceaseless flow it serves a twofold purpose. The fluid portion feeds the tissues and repairs the waste, while the tiny red corpuscles carry the oxygen from the lungs to all parts of the body, and return laden with carbonic acid to be expelled through the lungs. The heart itself is double, and each half contains two chambers, an *auricle* above and a *ventricle* below; and between these chambers valves are placed to prevent the blood from flowing back. The ventricles have thick, fleshy walls. The blood is received by the auricles, and passes into the ven-

tricles, whence it is sent out. The right auricle receives the dark red blood from the veins, and the right ventricle sends it to the lungs. The left auricle receives the purified blood from the lungs, and the left ventricle sends it on its way through the arteries and the capillaries, and thence through the veins to the right auricle again.


Fig. 118.—Diagram of the Circulation.

DIGESTION.—Digestion is the process whereby the nutritive portion of our food is made *soluble*, and is actually dissolved. The process is commenced in the mouth, but the stomach and the small intestines, the liver, and the pancreas or sweetbread are the chief organs of digestion. In the mouth the food is chewed and mixed with saliva, which partially changes the starchy foods into soluble sugar. In the stomach the food is rolled about, and mixed with another juice, the *gastric*, which exudes from the walls of the stomach itself. The partially digested food now enters the small intestine, where it gets mixed with the intestinal juice, with the bile from the liver, and with another juice from the pancreas, and these complete the digestive process. The digested food is taken up by little *hair-like* projections on the inner coat of the intestines, called *villi*. These villi are full of little tubes—the *lacteals*—which carry the milky-looking food through a number of *glands*, and then unite to form one common *duct*, which passes upwards through the chest and opens into a vein in the neck. The liver, a large

dark brown mass, lying chiefly on the right side of the abdomen, secretes the bile, but it also serves another important purpose—it is the store-house of the "fuel-food."

The internal organs of all vertebrate animals are constructed pretty much on the same plan as in man, and they serve similar purposes. As might be expected, however, from his superior intelligence, the brain of man is much larger in proportion to his size than that of any other animal.

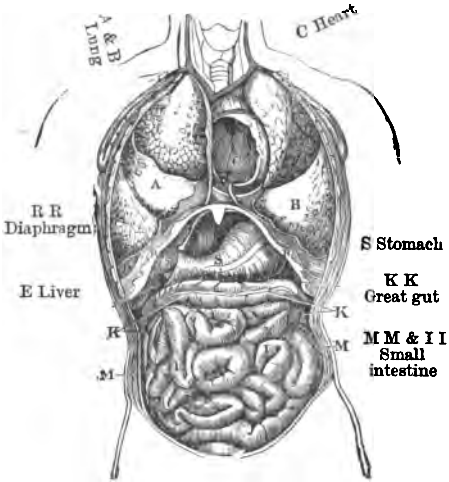


Fig. 119.—Thorax and Abdomen laid open.

The most remarkable variation in birds lies in the organ of respiration. In mammals the respiration is confined to the lungs; birds breathe not only through their lungs, but the air penetrates to every part of the interior of their bodies, even into the cavities of the bones. The lungs are fixed to the back of the thorax, and are comparatively small; their smaller size, however, is more than compensated for by the air-sacs which occupy the greater part of the cavity of the chest.

The brains of reptiles are much smaller in comparison with their size than those of mammals and birds, and the surface in all is quite smooth. The spinal cord and the nerve cords, on the other hand, are more fully developed. The lungs also are much less efficient organs for aerating the blood than in the preceding classes; the respiration is consequently less active and the blood comparatively cold. In most reptiles the heart has three chambers only, viz. one ventricle and two auricles. The single ventricle receives the purified blood from the lungs through one auricle, and the venous blood from the body through the other. A portion of this mixture is passed on to the lungs and the other part is sent out through the arteries and capillaries, to be returned again by the veins to the right auricle.

Fig. 120. —Brain of Frog.

Fishes live entirely in the water, and get the oxygen necessary for life from the air dissolved in the water, and not directly from the air itself. Lungs would be unsuitable for this purpose, and *gills* are therefore provided in place of lungs. These gills are fleshy, leaf-like organs, filled with blood-vessels, and placed on either side of the head. The water is always washing over and among the fringes of the gills, and the oxygen passes in through the thin walls of the blood-vessels, and the carbonic acid gas escapes into the water. Of course but a small amount of oxygen can be got in this way; the respiration is thus slow and the blood is cold. The heart has but two chambers. The blood is received in the auricle, whence it is passed into the ventricle, and thence pumped through the vessels of the gills to all parts of the body. The brain of fishes is small, quite smooth, and much less compact than in higher animals.

The internal organs of Vertebrates are formed on a common plan, modified when necessary to suit the needs of the owner. The same cannot be said of the Invertebrates,

although there is a considerable similarity in the organs of some of them. The first forms of animal life possess no special organs of any kind, the body consisting merely of a speck of a thin, jelly-like substance (see Lesson LXV., Part II.). All other forms have a stomach; it may be a simple blind sac, or a straight tube, or a distinct stomach with intestines, as in Vertebrates; but in some form or other it is always present. In connection with the digestive system, some of the more sluggish forms —such as the oyster, snail, and crab—have large and well-developed livers, while in the more active insects and spiders the liver is so small as to be hardly distinguishable. There is no brain proper, but in all except the very lowest tribes there are nerve masses connected by, and sending off, nerve cords. In the higher groups the nerve masses become larger and less in number. The blood is colourless, and the heart is wanting; but a circulation is carried on in tubes. Here again, in the higher forms, a swelling in one of the vessels forms a chamber, which may be considered as the simplest form of a heart. The respiration is for the most part carried on by means of gills of various shapes and forms; but the more active denizens of the air and earth—the insect and spider tribes for example—have breathing organs in the shape of air-tubes or air-sacs.

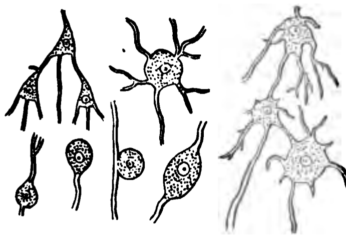


Fig. 121.—Ganglia and Nerves of an Insect.

PART II.

SPECIMEN LESSONS.

NATURAL HISTORY OBJECT LESSONS.

A Manual for Teachers.

SPECIMEN LESSONS.

THE lessons which follow are *specimen* lessons. All arrangement of systematic courses for the various classes is left to the teacher.

With the exception of *three* lessons on starch [pages 192-196], placed together to show how the same subject may be differently treated according to the ages and abilities of the scholars, the lessons are roughly arranged in order of difficulty; at the same time care has been given to the order of subject.

The earlier lessons are suitable for infants' schools, the intermediate for the junior scholars, and the later for the senior scholars of boys' and girls' schools. Less space is devoted to method in these lessons than in those of the former volumes, and less was needed. In most cases the arrangement is sufficient to suggest the method. Unless the teacher is very quick and skilful with the chalk and pencil, the outline figures should be drawn on paper, or on the blackboard beforehand.

LESSON I.

PAWS AND CLAWS (outline).

CAT, or dog, or both, or pictures, for illustration.

What are *paws*? What are claws? Why so named?

I. The Cat's Paw.

Call attention to—Its soft covering of *fur*; the soft *pads* underneath, their *use*, and why they don't *wear* out; the *toes* with the *claws*; the *claws*, their number, *five* on each fore-paw, *four* on each hind paw; their *shape*, *how* their sharp *points* are preserved, and *why*. Feel the claws, they are loose, they can be drawn back and hidden; the cat can put them out when she pleases. [The teacher may very well illustrate the action of the tendons with a fowl's foot. See Lesson LV.]

II. The Dog's Paw.

Call attention to—Covering of *hair*; the soft *pads* like the cat's; claws *blunt*, cannot be withdrawn. Why the dog does not require sharp claws—catches prey with teeth. *Why* the claws do not wear away. *Compare with cat's claws.*

LESSON II.

COCOA-NUT (outline).

FOR illustration a nut in the husk, sawn through the middle and the halves tied together. A nut without the husk. Picture of cocoa-nut tree.

I. The Nut as a whole.

Examine the nut in the husk. Three flat sides, surface smooth, brown in colour, hard to the touch.

Show the section, and call attention to the *fibre* of the outside covering, the hard shell, and the white kernel.

II. The Husk.

Husk can be separated into string-like pieces—*fibres.* Distribute some of these among the children and allow them to test: tough and strong. Tell them for what the fibres are used, and show some of the manufactured articles, such as matting, brushes, &c.

III. The Shell.

Remove the husk and the kernel from one half. Show the shell; it is very hard; try to break it; rough outside, smooth inside, brown colour. The basin-like shape of the half will suggest to what uses the shells may be put.

IV. The Kernel.

White colour, but brown on the outside. Distribute small pieces. Sweet to the taste, feels oily; an article of food in the country where it grows. Brought to this country in dried state, and the oil is taken out for the manufacture of candles.

V. The Milk.

Take the whole nut—shake it, some liquid inside. Show the "eyes;" open two and pour out the milk. Let the children look at, and taste, for its properties.

Show picture of cocoa-nut palm.

LESSON III.

COTTON AND WOOL (outline).

I. The Raw Material.

Distribute bits of "cotton-wool" and wool, and small strips of calico and woollen cloth.

Guide the children to examine the cotton and the wool separately, and tell all they can about each.

II. Comparison of.

Next they should compare the chief properties of the two. Thus both are—

(1.) Of a white colour.
(2.) Made up of fine threads.
(3.) Soft to the touch.
(4.) Warm to the touch.
(5.) Light.
(6.) Tough.
(7.) Bend easily.

Twist a little of each into a coarse thread to show how strong, and tough, and pliant these substances are.

Test each with the flame of a candle. "Cotton-wool" burns easily; wool frizzles up.

III. Manufactured Goods.

Now examine calico and woollen-cloth, and compare in the same way. Note especially that the woollen-cloth is warmer and softer than the calico. Show also that both are made of threads which cross each other in and out.

NOTE.—Another lesson of the same kind may be given introducing raw and manufactured silk.

LESSON IV.

AN EGG (outline).

FOR illustration two eggs, one of them hard-boiled.

I. Shell.—White colour, hard, breaks easily, smooth, thin, egg-shaped.

II. Skin.—Very thin, soft, smooth, elastic.

III. The "White."—Thick liquid, sticky, can see through it, almost colourless: *when boiled*—white, elastic, solid.

IV. Yolk.—Thick liquid, yellow: *when boiled*—yellow, solid.

LESSON V.

ACORN AND HAZEL-NUT (outline).

SUFFICIENT specimens of each in their capsules for each child to have one.

I. Parts.

A nut, and a cup in which it rests. Children may take nut out of cup.

II. The Cups.

Why so called? Compare as to shape, colour, and substance. Both smooth inside, but rough on the outside. The cup of the hazel-nut formed of small leaves joined together at the bottom. The edge of the acorn-cup forms a circle.

III. The Nuts.

Compare as to shape. Both longer than broad, and both are blunt pointed at one end, and rounded at the other. The hazel-nut (or filbert) is a little flattened, but the acorn is round like a slate-pencil.

IV. The Shells.

Alike in colour; brown when ripe. Shell of hazel-nut thicker and harder than that of the acorn.

V. The Kernels.

Both white and solid, and covered with a thin brown skin. They differ in taste. That of the hazel is sweet, that of the acorn a little bitter.

LESSON VI.

MILK (outline).

For illustration a glass of milk, and a glass of water.

I. Properties.—Liquid, white colour, can't see through it, sweet to taste. When "set" cream rises to top. Why? (Illustrate with cork in water.) Compare with water as to colour, taste, transparency, &c.

II. Uses—For food, for making butter and cheese.

Illustrate the formation of butter from cream by shaking a little warm cream in a warm soda-water bottle. And the formation of curds for cheese by adding a little vinegar to a glass of milk. Filter through cloth.

LESSON VII.

ONION, TURNIP, CARROT (a comparison).

Raw and cooked specimens for illustration.

I. Onion.—Call attention to the shape, the thin brown skin, the strong odour, and the hot, burning taste. Cut open to show the leaf-like layers; show thread-like roots. Compare with a cabbage, or with a lily-bulb.

II. Turnip.—In shape something like the onion; thick skin. Cut open to show solid flesh. Skin has hot taste, flesh sweetish.

III. Carrot.—Elongated shape, thin skin. Cut open to show the yellow and red parts. Sweet taste. Turnips and carrots are roots. Show the little rootlets.

IV. Comparison.

The children to be led to make this for themselves.

Onion.	*Turnip.*	*Carrot.*
Ball-shape (?)	Ball-shape (?)	Long.
Thin skin.	Thick skin.	Thin skin.
Layers.	Solid.	Solid.
Roots like threads.	A tap root.	A tap root.
Hot, burning taste.	Sweetish taste.	Sweet taste.
Strong odour.	Odourless.	Odourless.

LESSON VIII.

CAT AND DOG (a comparison *).

ILLUSTRATE by diagrams and pictures; but if possible with the animals themselves.

Cat.	Dog.
1. *Head*, roundish.	1. *Head*, elongated (usually).
2. *Skin*, very loose.	2. *Skin*, very loose.
3. *Covering*, fur.†	3. *Covering*, hair.†
4. *Paws*, with pads and claws.	4. *Paws*, with pads and claws.
5. *Claws*, curved, pointed; can be drawn back.	5. *Claws*, curved or nearly straight, blunt; cannot be drawn back.

* Omit such facts as four legs, two ears, and a tail.

† Explain the difference

Cat.	Dog.
6. *Eyes*, large; shielded by curtain in day-time.*	6. *Eyes*, large, but not shielded by curtain.
7. *Tongue*, rough † and dry.	7. *Tongue*, smooth and wet.
8. *Teeth*, with sharp points; motion of jaw, *up* and *down* only.	8. *Teeth*, with sharp points; motion of jaw, *up* and *down* only.
9. *Whiskers*, for feeling in dark.	9. *Whiskers*, for feeling in dark.

LESSON IX.

DOWN.

THE teacher should provide specimens of "body feathers," especially the finer kinds; also "eider-down," and if possible a dead bird.

I. Introduction

By means of a dead bird—a duck for preference—or by specimens of feathers, show that birds have two kinds of feathers. (1.) *Quill* feathers on the wings and tail. In most birds these are specially employed for locomotion. (2.) *Body* feathers intended as a protection from cold.

Show, also, how beautifully the feathers are arranged on the body, each overlapping the next and set in regular order, the whole forming a firm, warm coat.

The body feathers vary in weight, in size, and in fineness on different birds, and even on different parts of the same bird. The finest and lightest from the breast we call *down*.

* Explain why. † Explain for what purpose.

II. Properties of Down.

Distribute the specimens; call attention to the fact that *down* consists of small fluffy feathers, and assist the children by questions to discover those special properties of down for which it is highly prized, such as its *lightness*, *softness*, *warmth*, and *elasticity*.

III. Whence Obtained, and Uses.

Refer to the immense quantity of geese, ducks, and fowls used as food in this country. Good down for stuffing beds, pillows, cushions, &c., is obtained from these birds, and of course in large quantity. Besides this, we purchase yearly from other countries about two thousand tons of the same kind.

The best down is that obtained from a kind of wild duck, called the eider-duck, which frequents the rocky coasts of cold countries in the North. The down is called eider-down.

The eider-duck builds a simple nest of twigs, sea-weed, blades of grass, straw, or any similar material it can pick up; but it lines it with beautiful soft down plucked from its own breast. It is this down collected from the nests which is the lightest and warmest, and therefore the most valuable for making bed coverings and pillows. In some places the birds are looked after and tended as if they were poultry in a farm-yard, and during the breeding season they become quite tame. The farmer provides old boxes, boards covered with brushwood, and other snug corners in which the birds can build their nests, but in return he takes a portion of the eggs and down. The birds then provide fresh supplies, and the farmer again takes his share. When the process has been repeated for the third time, the male bird provides the down.

LESSON X.

A QUILL-FEATHER.

Provide at least one quill-feather for each child. They may be obtained from the poulterer, or from the nearest farm-yard.

I. Parts.

Call attention to and name the parts: *Quill, shaft, web.* Compare the parts.

II. The Quill.

Covered with thin skin inside and out. Remove this. *Quill*, a tube with walls which are *strong, light*, and *elastic*. Test for these properties: can be cut with a knife, but is softened in warm water and then can be cut more easily. Quill pen.

III. The Shaft.

Four sides. Filled with white substance—*pith.* Take out the pith and show that it is *tough, light*, and *elastic.* Walls of shaft, *tough* and *strong.* Children may try to break it.

IV. The Web.

Show long, flat pieces placed side by side, fixed firmly to shaft. Draw the fingers down the feather, the "leaves" are ruffled and separated. Draw fingers in opposite direction, leaves take their proper places, and the web becomes smooth again.

[If the children are sufficiently advanced to understand, show how the "laminæ" or leaves are lightly held together, and how they unite again after being separated. The "laminæ" are provided with a vast number of hooks made of thin fibres which project from the edges. Every hook is bent in a certain way. Those on one edge are long, flexible,

and bent downwards, while those which proceed from the opposite edge are shorter and firmer and turn upwards. When two leaves are pressed together so that the long fibres are forced far enough over the short ones their crooked parts fall over the angles formed by the crooked parts of the others, just as the latch of a door falls into the cavity of the catch fixed to the door post.]

LESSON XI.

GUTTA-PERCHA (outline).

FOR illustration a number of small pieces cut from a sheet; any manufactured articles.

I. Properties.

Distribute half the pieces among the children and put the other half in warm water. They will at once recognise that it looks like leather; they will feel that it is *tough*, *flexible*, and *strong*. By experiment it must be shown that it can be cut with a knife, and that it burns with a white flame, giving off much smoke, and a peculiar smell.

Distribute the pieces from the water. It is now *softer;* it can be worked with the fingers and the shape changed. It is *plastic;* it can be moulded into any shape. The children may mould it for themselves.

As it cools it gets hard again. Of what advantage is this property in making articles from it? Illustrate by making a small cup with thin walls. From this show another important property by putting water in the cup. The cup holds the water. Gutta-percha is *water-proof.*

II. Uses.

The uses of course follow from its properties.

Used for soles of boots and shoes. Why? Because flexible, strong, and waterproof. Why must we *not* put the soles near the fire? For bottles, inkstands, frames, whistles, walking-sticks, tubes for gas and water. All these articles are easily made when the percha is soft, and they become hard on cooling. Why must we *not* put hot water in vessels made of gutta-percha?

LESSON XII.

LEAVES.

Lessons on leaves may take one of three forms—the external form and appearance; the minute internal structure; the leaf in action. The idea of this lesson is to direct attention to the size, shape, colour, margin, surface, and veins of any common leaves which the teacher can place in the hands of children for examination and comparison. We will assume that we have for example the leaves of rhubarb, cabbage, scarlet-runner, and strawberry.

I. The Rhubarb Leaf.

Call attention to the footstalk and the blade. The *footstalk* is long, large, and fleshy; flat on one side, rounded on the other, reddish in colour and very juicy, the juice being sour to the taste. The *blade* is broad, and it has large veins which run from the footstalk like fingers from the hand; the colour of the upper surface is a darker green than that of the lower surface. The stalk and veins are smooth and covered with a fine thin skin easily removable when the leaf is young. The margin of the blade is not notched.

II. Cabbage.

Examine the cabbage leaf in a similar way, and compare with that of the rhubarb. For instance, the footstalk is short, strong, and fleshy, and runs as a great rib to the point

of the blade, while smaller ribs run from it to the edges, and so on.

III. Scarlet Runner.

Note that the leaf is in three pieces and that each piece has a footstalk joined to the larger footstalk of the whole leaf. Examine these footstalks; they are thin, weak, and grooved. Look at the blade, note its shape and the run of the ribs. Feel the surface of the cabbage leaf and then the scarlet-runner; the former is smooth, the latter rough. Why? The leaves of the scarlet-runner are covered with short, stiff hairs. Compare the colour of the upper and lower surfaces.

IV. Strawberry.

Long footstalk. Leaf in three pieces each on a short footstalk. Footstalks firm, tough, and covered with hair, grooved in front, rounded behind. Note the shape of the leaf; margins cut like a saw. Compare with margin of scarlet-runner leaf. Compare the colour of the surfaces.

NOTE.—When two or three other lessons have been given of the same kind the teacher may point to the following general conclusions.

(1.) Leaves are of two kinds, *simple* and *compound*. Simple leaves are those which have one blade on the footstalk. Compound leaves are those which have two or more blades, each with a separate footstalk, but all joined to one common footstalk.

(2.) The under surfaces of leaves are usually lighter in colour than the upper surfaces.

(3.) All leaves have veins which proceed from the footstalk, but they are arranged in different ways in different leaves.

(4.) The margins or edges of leaves are either smooth or cut and notched in various ways.

(5.) Leaves vary in shape, and size, and colour, and in various other ways, so that the leaf of one kind of plant can always be distinguished from the leaf of another kind.

LESSON XIII.

The three lessons which follow—on Starch—are intended to show the different treatment of the same subject for children of different ages.

STARCH I. (for infants).

FOR illustration: starch in powder and in sticks, a little powdered sugar, salt, chalk, flour, a large glass of water, and a muslin bag. Apparatus for "making" starch, a piece of linen or calico, and a flat-iron.

I. Properties.

Call attention to colour; compare with other substances, such as powdered sugar, salt, and chalk. (1) for colour, (2) for taste, (3) for solubility in cold water, (4) for feeling when pressed between the fingers.

Show how starch can be distinguished by touch. Next show the effect of boiling water on starch. Mix a little with cold water, and then pour in boiling water.

From this *illustrate* the "starching" of linen, and thus educe one common use.

Treat arrowroot with hot water, to show that this substance is really starch.

II. Whence and how Obtained.

Mix a little wheaten flour into dough, put the dough in a stout muslin bag, and knead the dough under water. The water soon becomes milky with starch.

LESSON XIV.

STARCH II. (for junior scholars).

FOR illustration: a potato, a little wheaten-flour, corn-flour, arrowroot, and sago; a glass of water and a muslin bag, a piece of new calico, and a little British gum.

I. Its Preparation.

(1.) Cleanse, peel, and rasp a potato, place in a muslin bag, and knead it with the thumb and fingers under water, in a glass vessel. The children will note the milky appearance of the water. This is caused by the tiny particles of starch. After a long time it settles down to the bottom of the vessel, and may be collected by filtering, or by pouring off the water and gently drying.

(2.) May be separated from wheaten flour as described in the last lesson.

II. Its Properties.

The more common properties may be gathered from the children by observation and simple experiment. It is a brilliant, white, granular powder, often sold in the shops in broken sticks; but these may easily be reduced to powder. When passed between the fingers starch gives a peculiar, harsh feeling, and it makes a crackling sound. It is heavier than water; is quite insoluble in cold water. Mixed with hot water it swells into a jelly-like mass, and is used in this state for "starching" linen.

The starch grains are really little bags containing starch, too small to be seen except under the microscope. Hot water causes these bags to burst, and set the contents free. When we evaporate the water from a solution of salt or sugar we recover the salt or sugar, but this is not the case with starch. Once mixed with hot water, or heated in water, the beautiful

white grains can never be recovered again. Why? The sacs holding the starch are all broken to pieces.

When baked at a moderate heat in an oven starch becomes soluble in cold water, and when mixed with water forms a kind of gum called *British gum.*

III. Kinds and Uses.

(1.) Potato, wheat, and rice starch are used chiefly for laundry purposes, and for making British gum. The latter is used in large quantities in the manufacture of paper and of cotton goods, for sizing and stiffening. Compare "writing" with "blotting" paper. The latter is porous, and absorbs the ink; in the former the pores are filled up with British gum. Rub a piece of new calico, a white dust is detached; this is the gum used in *stiffening*, and for giving a *gloss*. British gum is also the chief ingredient in the adhesive gum of envelopes and postage-stamps.

(2.) The starch from maize or Indian corn is called "corn-flour," and is used for making puddings, &c.

(3.) Arrowroot and sago are nearly pure starch. Arrowroot is obtained from the root of a plant, sago from the pith of the sago-palm.

LESSON XV.

STARCH III. (for senior scholars).

SKETCH of magnified starch grains, a few peas dry and soaked, a few sprouted grains of wheat, and a little iodide of potassium.

I. Storehouses for Starch.

Starch is one of the *three* chief products of "plant factories" (see Lesson LXVIII). It is found more or less abundantly in every plant. It is the chief form in which the food for the

future use of the plant is stored up. It is stored in immense quantities in seeds, especially the cereals, and in potatoes; and all our vegetable food contains more or less of it. We must look on starch, then, not so much as an article of utility in the laundry or manufactory; but as the important article of food as well for plants as for animals.

Call attention to the sketch on blackboard of starch-grains, showing the form in which the starch is stored, viz. in granules in cells. Show also that these granules take different forms and sizes in different plants, so that a mere glance at the granules under the microscope is sufficient to determine from what plant the starch was derived.

If a few grains are placed under the microscope and a drop of sulphuric acid be added the grains swell up and burst, showing that each in its dry state is a kind of bag contracted on its contents. A grain may be compared to a dry, wrinkled pea, and the swelling may be compared to the swelling of peas when soaked in water.

II. Chief Properties.

The first property of starch is its power of *combination* with water at a high temperature to form a thick, gelatinous mass. Heat has the same effect on starch as sulphuric acid, provided water is present. The little sacs swell and burst, and their contents combine with the water. Hence it is that soft liquid mixtures of starch become converted by boiling or baking into consistent puddings. Were it not for this property of starch there would be no puddings.

The second property of starch is its easy conversion into sugar. Without this property, given the puddings they would be useless, because indigestible. Although the plant-food is stored up in the form of starch it is not used in this form, but as sugar. As the seed begins to sprout the starch begins to change to sugar. Instance, bread from the flour of sprouted wheat is *sweet*. In the process of making malt, barley

is made to germinate by heat and moisture, and the starch is converted into sugar. Similarly in the animal kingdom the starch is converted into sugar before it becomes useful as food. In the saliva prepared in the salivary glands of the mouth there is a peculiar substance known as *ptyalin*. This ptyalin possesses the property of converting starch into sugar. This becomes mixed with the food during mastication, and the process of converting starch into sugar begins in the mouth.

The third property of starch is one which enables its presence to be detected. Starch is always coloured blue by iodine. To a few grains of iodide of potassium dissolved in a tumbler of water add a single drop of any kind of starch. The mixture becomes blue immediately.

III. Uses.

In this lesson the teacher may pass lightly over other uses and deal with starch as one of the chief foods *for keeping up the natural heat of the body, and for supplying the force necessary for movement and work.* As to how far the teacher may pursue the subject must depend on the knowledge the children have previously acquired; but at least they may learn so much of the chemistry of starch as a food as may be found in any one of the numerous little text-books on domestic economy found in every school.

LESSON XVI.

THE HORSE.

For illustration, pictures of horse and donkey.

The special points in the general appearance and structure of the horse to which the attention of little children should be drawn are:—

I. The Skin.

This is thick and covered with hair. Hair becomes much thicker as the winter comes on. Much of it falls off in the spring. Some owners *clip* their horses, to make them look nice and smooth. They should then be protected with cloths. Skin makes thick leather for soles of shoes.

II. The Head and Neck.

The neck has a long *mane* of hair, and the head has a *tuft* on the top. The eyes are large, and so placed that the animal can see on each side as well as the front. The ears are small and pointed; they show the feelings of the horse. The horse is said to "prick up" his ears as a sign of attention, or when he is expecting his food. A vicious horse throws his ears back; a frightened horse extends them forward.

III. The Tail.

The tail is thick and short and pointed, but covered with long coarse hair, which sometimes reaches down to the ground. People sometimes cut the tail short; but this is not kind, because it prevents the animal from whisking away the flies which tease it.

IV. The Teeth.

If the teeth of the horse were arranged like ours we could not put the "bit" in his mouth. Between the *front* and the *back* teeth there is a long space; the bit fits into this space.

V. The Hoof.

The hoof is large, solid, and round, made of a kind of horn, like the nails of our fingers. [See Fig. 100, Part I.] They can be cut without hurting the animal, as we cut our nails. But if we cut too deep it gives great pain, just as when we cut our nails too deep. The hoof grows as fast as it wears out, but the domestic horse is provided with iron shoes, to preserve the hoofs on the hard roads. The

smith takes care not to drive the nails into the "quick," or the horse would be lamed.

Compare the donkey with the horse.

LESSON XVII.

THE COW AND THE SHEEP.

ARTICLES for illustration: cow's or sheep's hoof, skull, cow's hair, wool, horns, and any manufactured articles.

This lesson may take the form of a comparison between these animals; first as to general structure and habits, and secondly as to special uses, alive and dead.

I. General Structure and Habits.

The points of likeness to which the attention of the children should be directed are the *cloven hoof* on each foot, the *absence of teeth* in the front of the upper jaw, and the presence of the *hard pad* in their place, the *horns,* and the practice of "*chewing the cud.*" Explain "chewing the cud." The food is swallowed into a large bag without chewing. When the animal is at rest this is brought back through a second stomach a little at a time, properly chewed, and then swallowed into the third stomach, whence it passes into the fourth, the true stomach.

The points of difference may be confined to the covering of the skin, the tail, the size of the animal, and the surface of the horns. The covering of the cow consists of short hair, like that of the horse; that of the sheep of long, twisted hair, which we call "wool." The wool forms a very warm covering. Left to itself it would come off in the early summer, and a new fleece take its place by the beginning of the next winter. The tail of the cow is long, covered with hair, like

the skin, but has a tuft of longer hairs at the end. That of the sheep is also long, but covered with wool. In this country the tails of young lambs are often cut off. The horns of the sheep, when present, are always rough and knotty on the surface; those of the cow are smooth.

II. Uses.

The skin.—That of the cow makes thick leather, that of the calf thin leather for "uppers." Many kinds of leather are made from sheep-skins, such as *morocco, kid,* and *wash* leather.

The hair.—Cow's hair is used in mixing mortar for plastering, especially ceilings. Wool is used for making all sorts of "woollen goods."

The flesh.—Used for food; some of the fat for *tallow.* The milk from the cow is a most important article of food; butter and cheese are made from it. Sheep's milk is used in some countries.

LESSON XVIII.

HONEY AND WAX.

A PIECE of honey-comb with the honey (if sufficient for each child to have a small piece, so much the better), and any articles made of wax should be obtained for this lesson.

I. Honey-comb.

Let the scholars examine a piece of "comb" from some of the cells of which the honey has not been removed.

Call attention to:—

(1.) The *cells*, their size, shape, and wax walls.

(2.) The *honey*, its semi-fluid state, colour, taste.

The cells are made and the honey is placed in them by bees. Where do the bees get the wax and the honey?

II. Honey.

Bees collect the sweet juices from the flowers, and sometimes from leaves, by means of their long tongues. The tongues are, of course, very small; but little tufts of hair are set on them, and by means of these the juices are swept up, and then carried by the tongue into the mouth. From the mouth they are passed, not into the stomach, but into a little bag within the body, which is called the *honey-bag*. When this bag is full the bee flies off to the hive. Here it is carried from the honey-bag back into the mouth, and thence placed in the prepared cells for winter use, or given to feed their friends, who, being at work in the hive, cannot find food for themselves. The most curious point about the honey is the change which takes place in the honey-bag. The flower juices go into the honey-bag as sweet juice, but what comes out is *honey*, different in colour, flavour, and smell from the sweet juice which was put in.

III. Wax.

The wax for making the cell-walls is not collected; it comes from the body of the bee. Between the rings of the body on the under surface we find *six* little flaps, these cover six little pockets made of thin skin. The bees must rest while these pockets are being filled with wax. They are said to hang in festoons from the top of the hive for twenty-four hours, and at the end of this time the wax can be seen forcing the pocket-flaps open. This wax is taken from the pockets by other bees, in bits, which they knead in their mouths like a mason works his mortar, or a glazier his putty. It comes from the mouth as a tiny white ribbon, and with this prepared wax other bees make the cells.

Large quantities of bees'-wax are used for making the best candles; also for artificial flowers and fruit. But for these purposes it has to be cleansed. The empty comb is first melted in boiling water and then strained through hair bags.

In this state it is yellow. When wanted of a nice *white* colour it is cut into shavings and laid on canvas in the open air.

The properties of wax may be gathered from the children.

LESSON XIX.

IVORY.

The articles required for this lesson are rough and polished ivory and bone, and beyond these, as many specimens of tusks and articles made of ivory as the teacher can command. Also pictures of tusk-bearing animals.

I. Natural History.

Ivory is the name given to the dentine of teeth large enough to be available for industrial purposes. The incisor teeth or *tusks* of the elephant, hippopotamus, walrus, and narwhal furnish pretty nearly the total supply. [Show pictures of these animals. Show incisor teeth. Refer to teeth of Rodents.] The tusks are hollow at the base and gradually become solid towards the smaller or pointed end.

Elephant tusks yield the finest ivory. The tusks vary in length from a few inches to as much as *ten* feet. They occasionally weigh as much as 150 lbs. or 160 lbs., but the average is from 10 lbs. to 20 lbs. The tusks of the Indian elephant are much smaller than those of the African, and it is only in the latter species that the female as well as the male is armed with these formidable weapons. A small number of *shed* tusks are picked up by the natives for sale, but the greater number are obtained by hunting and destroying the animal.

Large quantities of tusks of an extinct long-haired elephant—the mammoth—are found in the frozen soil near the

rivers in Northern Siberia. The ivory from these tusks furnishes material for Russian ivory-turners. The quality of the ivory, however, is inferior, and but little used in this country.

The ivory from the tusks of the hippopotamus is harder and whiter, and is less prone to turn yellow than elephant ivory. It was at one time much used by dentists for making artificial teeth.

II. Properties.

Compare polished plates of ivory and bone. The former is distinguished by curved lines of great regularity and beauty. The transverse section of an elephant tusk shows these streaks running from the centre to the circumference, not in straight, but in curved lines turning right and left and thus crossing each other. [Compare with the "engine-turned" watch-case.] Ivory may also be distinguished from bone by the closeness of its *grain*, and by the beautiful *polish* which it takes.

In thin plates ivory is *translucent*, more so than paper of the same thickness. It is *elastic*, *very hard*, and less liable to crack than bone.

III. Uses.

It is owing to its strength, durability, hardness, and beauty when polished, that ivory is *carved* or *turned* into so many articles, useful and ornamental. The children will be able to enumerate many articles made of ivory. Handles of knives and forks, organ and pianoforte keys, combs, backs of hair-brushes, paper-knives, napkin-rings, and thin sheets for miniature painting, and for writing tablets are among the articles of utility.

IV Vegetable Ivory.

This substance, which resembles real ivory and is sometimes used as a substitute, is taken from the nut of a species

of palm growing in South America. The nut at first contains a sweetish milky fluid which gradually hardens as the nut ripens until it becomes what is known as vegetable ivory.

Note.—In 1883, 13,597 cwt. of ivory teeth were imported, valued at £640,000, and 24,628 cwt. of vegetable ivory, valued at £18,000. The vegetable ivory is brought mainly from South America.

LESSON XX.

SEEDS AND SEEDLINGS. I.

I. Preparation.

With a little preparation this lesson may be made exceedingly interesting and instructive. The first object is to show how seedlings are developed from seeds, and of what parts the seedlings consist. Fill a pot with fine clean sand, and plant a score or more of the common field bean half an inch deep. Moisten the sand and set aside in a warm room. Care must be taken that the sand does not become dry. It is a good plan to cover the pot with a sheet of glass to prevent evaporation. In a few days the seeds will begin to sprout, that is the *seedlings* will begin to grow. [The time necessary for germination depends on the temperature. At 55° or 60° Fah. the leaves will be seen emerging from the sand in six or seven days. Old seeds require more time than new.] Now take another pot of sand and plant a few more seeds, and when these begin to germinate plant a third set. In about three or four weeks all the seedlings will be growing. To complete the set soak a few more seeds for twenty-four hours before the time fixed for the lesson and the preparation is complete.

II. Examination and Comparison.

The plants must be carefully removed from the sand and

placed on the desks in front of the scholars, who will arrange them under the guidance of the teacher in a series, from the largest to the smallest, the latter of course being the soaked seeds which have not germinated.

The children will now carefully examine the plants, and, guided by questions from the teacher, will discover for themselves all the points of difference and resemblance. Firstly, look at the soaked seeds. They split lengthwise into halves forming fleshy lobes,* and show a little *cone-like* body between them but close to one edge. Now take the plants which have made the least growth, and note what changes have taken place. The lobes which make up the bulk of the seed are greenish, fleshy *seed-leaves.* The little cone-like body has thrown out *roots* from the pointed end, and the first *green leaves* from the opposite end, and the part between forms the *stalk.* In a similar way examine the other two sets, with a view to bring out the changes which have taken place by growth, and to compare and match the parts which correspond in the plants, and in the seeds.

III. The Lesson.

The lesson to be impressed on the children is that the young plant is laid up in the seed, and that it needs only warmth and moisture to start it into active life.

LESSON XXI.

SEEDS AND SEEDLINGS. II.

I. Preparation.

The next step is the comparison of seedlings of different plants. Take, for example, the seedlings of the *pea, oak,* and

* If the haricot or French bean is used the seed-lobes will be carried to the surface and above with the stalk.

Indian-corn. The *sets* may be prepared by the method shown in the last lesson, but the children will probably be interested to see them grown in another way; for instance, upon wet paper, or in cocoa-nut fibre, or on a damp sponge. For paper planting use thick blotting-paper on a sheet of glass. Moisten with warm water, spread the seeds, and cover with another sheet of the paper. The whole must be kept moist and warm. [The interest in the lesson will be further enhanced if the teacher will take the trouble to germinate two or three acorns and a grain or two of Indian-corn a fortnight or three weeks before the first of the paper plantings. Immediately the seeds have sprouted suspend them carefully by a thread, or upon a perforated card, over water in a clean glass bottle or tumbler, so that the roots may be beneath the surface of the water, and the seed-leaves above. The roots will spread through the water and the leaves will expand in the air.]

II. Examination and Comparison.

The seedlings of the pea, in the various stages of growth, may be examined first, and compared with the embryo in the seed. It may next be compared with the seedling of the bean. The main parts correspond; but in the pea the seed-leaves remain within the husk or skin of the seed. The tiny embryo lengthens just enough to get out of the husk, and then the roots issue from the lower end of it, and a strong leafy stem is developed from the upper end. The seedlings of the acorns may next be examined, and compared with those of the pea and bean.

A more important comparison is that between the pea, bean, or acorn, and the Indian-corn, and the special points to note are—

(1.) *Two* seed-leaves in the bean, pea, and oak.
One seed-leaf in the Indian-corn.

(2.) The leaves of the bean, &c., unfold in *pairs.*

The leaves of Indian-corn unfold *singly* and on *alternate* sides.

(3.) The *roots* of the bean, &c., consist of a main stem and branches.

The *roots* of the Indian-corn form a cluster of hair-like fibres.

(4.) The *veins* of the leaves of the bean, &c., are branched and form a network. [See page 36.]

The *veins* of the leaf of the Indian-corn run from the base to the point side by side. [See page 36.]

This comparison of the veins can be best made in the specimens of larger growth.

III. The Lesson.

The lesson to be drawn is that the seeds of some plants enclose *two* seed-leaves, while others enclose only *one* seed-leaf. And the children may be told that with the exception of ferns, sea-weeds, and mosses, all the plants in the world may be arranged in two classes: those with *two seed-leaves* and those with *one seed-leaf.* The leaves of the former have branched veins in a network, those of the latter are straight-veined, the veins running side by side.

To the first class belong most of the plants of our own country. Plants of the second grow mostly in hot countries; but we have specimens in the grass, the corn, and the onion.

LESSON XXII.

OLIVE OIL.

For illustration provide specimens of the oil, and the pickled fruit; also a picture of the tree.

I. Properties of the Oil. (To be shown by experiment.)

(1.) Weight.—Pour a few drops on water in a bottle;

shake well; it breaks into tiny drops which float in the water. On standing, these quickly ascend to the surface, forming a thin layer of oil. Olive oil is the lightest of all the fixed oils. (See page 69.)

(2.) It is *inflammable* and burns beautifully in a spirit-lamp through a wick. It is too expensive, however, to be used for lighting purposes.

(3.) It becomes solid at a temperature considerably above the freezing-point of water. Stand a little in a test-tube in melting ice, it soon becomes solid.

(4.) Other properties such as its semi-transparency, and softness to the touch, children will discover for themselves.

II. The Tree and its Fruit. (For description see page 69.)

Cut in pieces a few of the pickled unripe fruit to show the pulp whence the oil is obtained, and the stone within. Taste the pulp: it is oily, rough, and bitter.

Show how the oil is obtained by pressure. Three qualities are obtained. The first by gentle pressure in coarse bags from the best hand-picked fruit. This, the best and purest oil, is called *virgin oil.* A second quality is obtained by warming the pulp, and then applying gentle pressure. This does not, however, extract all the oil, and a third and inferior quality is produced by boiling the crushed pulp in water.

III. Uses.

In countries where the olive-tree grows the purest oil takes the place of butter and cream. In our own country it is chiefly used in cooking, and for salads. The commoner kinds are used in the manufacture of soap.

LESSON XXIII.

LIBER.

ARTICLES for illustration.—As many specimens of inner bark as the teacher is able to obtain: but common bast, raw hemp, and raw flax must be included. Also specimens of manufactured goods.

I. What is Liber?

Take twigs of the common lime-tree, or stalks of nettles, or any convenient stems from which the children may discover the tough, stringy inner layer of bark. This inner layer is called *liber*, and sometimes *bast* or *bass*. Before the invention of paper some kinds of inner bark were used as writing-material. Hence its name *liber*, or book. Or it may have taken its name from the fact that the inner bark consists of thin layers like the leaves of a book.

Liber fibres are long and tenacious, and in some plants they are sufficiently tough, pliant, and strong to be put to a variety of useful purposes. The coarser kinds are made into rope, twine, netting, mats, sails, and so on. The fine kinds are woven into the finest materials for wearing apparel, &c.

II. Kinds of Liber.

(1.) *Bast.*—This is the inner bark of the lime-tree, and is used in Russia for the manufacture of mats, ropes, shoes, hats, and other articles. Several millions of Russian mats are imported into this country every year. They are used chiefly for packing furniture for removal, and for covering young plants to protect them from the frost. [The teacher will probably be able to show the children one of these mats.]

(2.) *Flax.* Show how the flax fibres are separated from the hard parts of the stalk of the flax-plant, and how they are prepared for spinning (See page 82.)

Show specimens of raw flax, and of the manufactured goods, and compare the latter with cotton goods.

New Zealand Flax is prepared from a sedge-like plant growing in marshy situations, and near the sea-coast.

(3.) *Hemp.*—To be dealt with in the same way as flax (see page 84), and the manufactured goods compared with both linen and cotton cloth.

Manilla hemp is a fine kind of hemp prepared from a species of plantain.

(4.) *Other kinds.*—A fibre much superior to that of flax or hemp can be obtained from a kind of nettle which grows in India. In gloss and fineness it resembles silk. The difficulty and cost of preparation, however, prevent its general use.

The people of India manufacture very curious sacks from the liber of a tree common in some parts of the jungles. "A branch is cut corresponding to the length and breadth of the sack wanted. It is soaked a little, and then beaten with clubs until the liber separates from the wood. The liber in the form of a sack is then turned inside out, and the wood is sawn off, with the exception of a small piece left to form the bottom of the sack. These sacks are in general use among the villagers for carrying rice."

A very beautiful kind of liber is obtained from a tree which grows in Jamaica. When the layers are separated they have the appearance of delicate lace. Hence the tree is called the vegetable lace tree.

LESSON XXIV.

KINDS OF ANIMALS. MAMMALS AND BIRDS.

(A first lesson in classification.)

I. Introduction.

Ask the children for names of animals which *walk*, *fly*, *crawl*, and *swim*. Write the names as given on the black-

board, adding such others as may be necessary for the teacher's purpose.

Suppose the written list to be as follows:—*Horse, crab, snake, bat, sparrow, eagle, cow, owl, cat, whale, duck, herring, seal, robin, serpent, snail, sheep, worm, mackerel, toad.*

II. First Step.

Direct the children to arrange these animals in four *classes* according to the method of locomotion, and write on the blackboard thus:—

1st Class.	*2nd Class.*	*3rd Class.*	*4th Class.*
Walking Animals.	*Flying Animals.*	*Crawling Animals.*	*Swimming Animals.*
Horse	Bat	Snake	Whale
Crab	Sparrow	Serpent	Duck
Cow	Eagle	Snail	Herring
Cat	Owl	Worm	Seal
Sheep	Robin	Toad	Mackerel.

We have thus grouped together into classes certain animals as they are alike in one particular—the way in which they move about. The children may add to the number. But it does not seem natural to place the crab and the horse together, or the worm and the toad, or the duck and the herring. The fact is, in grouping animals together it is not satisfactory to look to one particular only, but to many; and our great aim should be to place together those which are alike in the *greatest number of particulars.*

III. Second Step.

Now let us look a little more closely at the animals which we have placed in the four classes.

1. *The walking animals.*—Look at the covering of the skin. The horse, cow, cat, sheep are all covered with hair, for fur and wool are but special kinds of hair. The crab has an

outside shell and no hair. Children all know that the horse, cow, cat, and sheep have bones inside their bodies, and I daresay most of them know that the crab has no bones inside. Here is a second important particular in which the crab is unlike the other walking animals. Again, the horse, cow, cat, and sheep feed their young with milk, which they make in their own bodies. The mother crab lays eggs, and does not attend to her young at all. Lastly, if we could feel the bodies of these animals we should find that those which feed their young with milk have *warm* bodies, like our own. The crab, when living, feels cold to the touch. So we see that the horse, cow, cat, and sheep are alike, not only in the way they move about, but also in four other important particulars.

(*a.*) The hairy covering of the skin.
(*b.*) Having internal bones.
(*c.*) Feeding their young with milk.
(*d.*) Having warm bodies.

The crab has none of these, and therefore we strike it out from our *First class.*

2. *The flying animals.*

Now look at the *Second class.* The covering of all the birds consists of *feathers,* that of the bat is a *hairy skin.* Birds lay eggs, and when the young are hatched feed them with solid food. The bat *suckles* her young, like the cat. All the animals in the second class are alike in having internal bones and warm blood. We see, therefore, that the birds are all alike in—

(*a.*) The feather covering.
(*b.*) Having internal bones.
(*c.*) Laying eggs.
(*d.*) Having warm bodies.

But the bat, though like the birds in two of these particulars, is like the *First class* in all except the method of locomotion. We must therefore promote the bat to the *First class.* Our First and Second class will stand thus:—

First Class.	Second Class.
Horse.	Eagle.
Cow.	Sparrow.
Cat.	Robin.
Sheep.	Owl.
Bat.	

Mammals.	*Birds.*
(*a.*) Have internal bones.	(*a.*) Have internal bones.
(*b.*) Have warm bodies.	(*b.*) Have warm bodies.
(*c.*) Hairy covering to skin.	(*c.*) Feather covering to skin.
(*d.*) Suckle their young.	(*d.*) Do not suckle their young.

The above should be written as the final summary, and the children should be asked to add to the classes, especially the first. The First class are named Mammals, from *mammæ,* the glands which secrete the milk.

LESSON XXV.

KINDS OF ANIMALS. REPTILES AND FISHES.

(A second lesson in classification.)

In this lesson we have to consider the *Third* and *Fourth* classes, viz., crawling and swimming animals. [See last lesson and write the names on the blackboard.]

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1. *The crawling animals.*

First as to their coverings. The snake and serpent have scaly coverings, the toad has warts on a naked skin, the snail and worm have naked, slimy skins. The snake and serpent and toad have internal bones, the snail and worm have none. All lay eggs except some of the snakes and serpents, and all have *cold* bodies.

From our Third class we reject the worm and snail because they have no internal skeletons. As we shall learn by-and-by, there are other important differences in their structures.

2. *The swimming animals.*

The children will answer at once that the duck should be promoted to the class of Birds. There will not be much difficulty either in transferring the seal to the Mammals. But the whale is so like a fish, and is so often commonly considered as a fish, that the children will need to be told why it is a mammal, and not a fish. It suckles its young, which no fishes do; and it has warm blood, which no fishes have; and it is therefore as much a Mammal as a horse or a cow. The herring and the mackerel have their skins covered with scales. They have, as every child knows, plenty of internal bones. They do not suckle their young, their bodies are cold to the touch; and there is another important particular in which they differ from all the animals which we have placed in the other classes, they have gills for breathing instead of lungs.

We may now give our *Third* and *Fourth* classes their proper names, and arrange all the animals in their proper classes. The creeping or crawling animals are called *Reptiles,** a word which means *creeping.* The *Fourth class* are *Fishes.*

Thus we have:—

Mammals.	*Birds.*	*Reptiles.*	*Fishes.*
Horse.	Sparrow.	Snake.	Herring.
Cow.	Eagle.	Serpent.	Mackerel.
Cat.	Owl.	Toad.	
Sheep.	Robin.		
Bat.	Duck.		
Whale.			
Seal.			

* This is not a good name, because some of the reptiles do not crawl.

The children should be encouraged to name other animals belonging to the four classes, and give their reasons for placing in the particular class. Of mammals, birds, and fishes they will know plenty, but in the case of reptiles the teacher will probably have to lend his assistance.

The chief characteristics of the four classes arranged in a tabular form will be of considerable service in future lessons.

MAMMALS.	Possess internal skeleton.	Breathe by means of lungs.	Have warm blood.	Skin covered with hair.	Suckle their young.
BIRDS.	Possess internal skeleton.	Breathe by means of lungs.	Have warm blood.	Skin covered with feathers.	Lay eggs from which young are hatched.
REPTILES.	Possess internal skeleton.	Breathe by lungs or gills.	Have cold blood.	Skin covered with scales or naked.	Lay eggs from which young are hatched.
FISHES.	Possess internal skeleton.	Breathe by gills.	Have cold blood.	Skin covered with scales.	Lay eggs from which young are hatched.

LESSON XXVI.

KINDS OF ANIMALS. MAMMALS.

(A third lesson in classification.)

I. Introduction.

Question the children on the meaning of the word mammal, and on the chief distinguishing features of mammals as given in Lesson XXIV. In one of these particulars, the possession of a bony skeleton, they are like all the classes we have dealt

with. They are like birds also, in having warm bodies. They stand alone in suckling their young, and in having the skin covered with hair of some kind.

Now, as in the first lesson on classification, let the children name all the animals they can which belong to the class of mammals. Write the names as given on the blackboard, and add any others as may be necessary for the lesson.

Suppose the list to be: *horse, cow, cat, sheep, dog, elephant, goat, deer, monkey, mouse, bat, rat, rabbit, hare, hedgehog, mole, whale, seal, ant-eater, kangaroo, gorilla, lion, tiger.*

II. Orders of Mammals.

The teacher may now guide and assist the children to arrange these animals in something like *order;* and as the groups or *orders* are formed, he may name other animals belonging to the same group, and show pictures of any which are unfamiliar.

1. Which animals use all the feet as hands? The monkey and gorilla. Put these together and add the baboon. The gorilla is an ape, and we place all *Monkeys, Apes,* and *Baboons* in one group, and call it *Four-handed* (Quadrumana).

2. Which animals have wings, and fly through the air? The bats. The bats form a separate group, the *Wing-handed* (Cheiroptera). They are so called because the hand is made into a wing.

3. Which animals feed on flesh? The cat, dog, lion, tiger, seal. These are put into another, and called *flesh-eaters* (Carnivora). The leopards, bears, jackals, and hyænas also belong to this order.

4. Which animals feed on insects? The mole and the hedgehog; they have teeth with sharp points for crushing. With the *Shrews,* they form the order of *Insect-eaters* (Insectivora).

5. Which animals have broad, cutting teeth in front, with

which they *gnaw?* The mouse, rat, rabbit, hare. These are *gnawers* (Rodentia). To this order belong an immense number of animals. The beaver, squirrel, field-vole, porcupine, and prairie-dog are members of this order.

6. Which of the animals live in the water? The whale. The dolphin and porpoise are put in the same group with the whale, and the order is called *Whale-like* (Cetacea).

7. Which of the animals "chew the cud?" The cow, sheep, goat, and deer. They form the order of *cud-chewers* (Ruminantia).

8. Which of the animals have no teeth? The ant-eater. The sloths are placed in the same group with the ant-eaters. They are called *toothless* animals (Edentata). [As a matter of fact the sloths have back, but no front teeth.]

9. Which of these animals have very thick skins? The horse and the elephant. The pig, donkey, hippopotamus, tapir, and many other animals belong to the order of *thick-skinned* animals (Pachydermata).

10. One animal is left, the kangaroo. The kangaroo has a pouch in front of the body, in which it carries its young. All animals possessing these pouches are *pouched* animals (Marsupialia).

LESSON XXVII.

CHEWING THE CUD.

ILLUSTRATE by diagrams and pictures.

I. Introduction.

The teacher may very well introduce this lesson with a conversation with the children on the way in which domestic animals take their food into their mouths, and then chew it.

If the food be small, or in a liquid form, the cat and dog

lap it up with the tongue; if it consists of flesh they cut it to pieces with the side teeth, moving the lower jaw up and down only with a jerking motion. There is no grinding of the food. The horse collects loose food with his delicate lips. Grass he bites off with his front teeth. Holding the grass as in a vice he gives a jerk of the head and off it comes. Then he grinds it with his large molars, the lower jaw having a side-to-side motion for the purpose.

The cow collects her food with her long tongue. In eating grass a sweep of the tongue brings it within the lips. Here it is taken hold of and held between the front teeth of the lower jaw and the hard pad which takes the place of the teeth in the upper jaw; a jerk of the head tears it off.

II. Collecting the Food.

Now, if you look at a horse and a cow while feeding you will see that the cow feeds much faster than the horse. She chews her food scarcely at all, and swallows it very quickly. Children, no doubt, will have been told that to swallow food without properly chewing it is not good, neither is it. What of the cow then? The cow, sheep, goat, deer, and many other animals collect their food and swallow it into a large bag (called a stomach) without much chewing; and when they have collected a sufficient supply they lie down, and then quietly set to work to chew it properly, a little at a time. This is called "chewing the cud."

III. Chewing the Cud.

Watch a cow, a sheep, or a deer in the act of chewing the cud. The animal gives a sort of hiccup, then slowly grinds away for a certain time, and then swallows the chewed food. After a second or two, another hiccup follows, and the grinding begins again, and this process is repeated till all the food is masticated. All the animals which chew their food in this way are called *Ruminants*, a word which means "chew-

ing the cud." Ruminants are all provided with a special kind of stomach adapted to the purpose of rumination. The illustration (for blackboard) will explain the structure. [See Fig. 1 Appendix.]

a is the *gullet* up and down which the food passes.

b is the *paunch*, a large bag for storing the unchewed food.

c is the *honey-comb*, so called because the lining consists of cells like the honey-comb of the bee.

d is the *manyplies*, so called from the many folds or *plies* in the lining.

e is the reed or true stomach.

The process of rumination seems to be thus:—When the animal has ceased feeding, and wishes to chew, a little of the food is passed from the paunch into the honey-comb, and thence forced into the mouth. Here it is mixed with the saliva and properly masticated, and then swallowed again. But this time it does not go into the paunch or honey-comb. It is in a semi fluid condition and passes along the manyplies and into the true stomach, where it is properly digested.

In the camel and llama the manyplies is wanting, and the cells of the honey-comb are much enlarged and made receptacles for holding water. They are closed in front, that is internally, but there exists an opening which can be opened or closed at the will of the animal. Other and smaller cells of the same kind are also found in the walls of the paunch, and these also serve for the storage of water.

NOTE.—An interesting lesson to follow the above may be given on the camel. The special points to be noticed are the *water-cells*, the structure of the *feet*—spreading *pads* taking the place of hoofs, the callous *pads* of hardened skin on the leg joints and chest, the peculiar structure of the *nostrils* for keeping out the sand, and the *teeth* in front of the upper jaw.

LESSON XXVIII.

HORNS AND THEIR USES.

ILLUSTRATE with diagrams, a cow's or other horn, and articles made from horn.

Let the children name all the animals they know which possess horns. Write the names on the blackboard. It will be found that nearly all the horned animals belong to the "ruminants." [Explain.]

Horns are of two kinds, and these kinds differ in character and properties, and in their mode of growth.

I. Horny Horns. (*Permanent horns.*)

The horns of oxen, sheep, goats, and antelopes are all *hollow*. They are formed of a material very much like the nails of our fingers, which we call *horn* from its source. These horns grow during the whole life-time of the animal, and are never *shed* * except by accident. If the horn of a cow or an ox gets knocked off, as it occasionally does, a bony core is seen projecting from the head like a small cone; on this the real horn was fixed. The core is covered with a very sensitive skin full of nerves and blood-vessels. We may cut the real horn without causing pain or injury, just as we may cut our finger nails at the edge; but if we cut the skin of the core it causes intense pain, such as we feel in our fingers when we cut the nails too close.

The horns of ruminants are occasionally straight, but more often they are bent or curved, and not unfrequently twisted, and they are of all lengths up to five or six feet.

II. Bony Horns. (*Deciduous horns.*)

The horns of the various kinds of deer are formed of a kind of hard bone, and they fall off and are renewed every

* With one exception, the American antelopes shed their horns.

year. With the single exception of the reindeer, the horns are confined to the males. The method of growth of these horns is curious and interesting. Take the common red stag as an example. The horns are shed early in the year. Soon two little knobs may be seen to occupy the place of the future horns, and they are covered with a beautiful soft, velvety skin. These knobs grow very fast, and very quickly indicate the shape of the future horn. The velvety skin is full of blood-vessels through which the blood courses depositing animal and mineral matter, and adding to the growth of the horn as it passes along. If the horn be grasped at this time it will be found quite hot. In about *eight* or *ten* weeks the horns will have attained their proper dimensions for that year. The blood-vessels of the skin pass through projecting bony rings at the base of the horn, and when the growth is complete these rings thicken and close the blood-vessels. Left without nourishment the skin now shrivels and peels off, or is rubbed off by the animal against the trunks of trees. Although the horns fall off every year, yet the horns of each succeeding year are more fully developed till the animal becomes adult, when the horns are large and long, and divided into numerous spreading branches. These bony horns are called *antlers*. Some of the antlers, like those of the stag or red deer, have cylindrical branches tapering to a point; others, like the fallow deer and reindeer, have flattened branches.

III. Uses.

Horns are used for a variety of purposes; the bony horns of the deer-tribe chiefly for knife and fork handles; the horny horns of the ox-tribe for combs, drinking-cups, knife and fork handles, &c. The term *horn* is usually applied to the soft horn of the ox, sheep, &c. This horn is similar in structure to nails, and hoofs, and claws. It is fibrous, and the fibres are elastic and flexible. Cut into slices it is almost

transparent. [Formerly used for lanterns.] Soaked in hot water it becomes soft, and may then be pressed out quite flat, and stamped and cut into the various articles needed. The tips of the horns being solid are used for making buttons.

LESSON XXIX.

PARTS OF A FLOWER (outline).

SENIOR INFANTS AND LOWER STANDARDS.

ANY common flowers will serve for this lesson provided they are sufficiently large for the children to see the parts with the naked eye. Each child should be provided with one or two specimens.

In this lesson we take the wall-flower and tulip as examples. These flowers come into blossom about the same time in the spring.

I. The Wall-flower.

The children must be led to point out the *parts* themselves, the teacher giving the *names* only. The flower is set on a stalk. Outside we see *four* little green leaf-like bodies; these form the *calyx*—covering—and each part is a *sepal.* Then follow *four* more leaf-like bodies, but these are coloured. Together they form the *corolla*—little crown—and each separate piece is a *petal.* Inside the corolla we find *six* little *bags* set on stalks: four long and two short. These are the *stamens*; the bags are the *anthers,* and the stalks the *threads,* or *filaments.* In the anthers we find a kind of dust called *pollen.* In the centre of the flower we find another organ, the *pistil.* The pistil is made of the long *ovary* containing the *ovules* or young seeds below, and the *stigma* above. The ovary is *two-celled.*

Show by a sectional diagram (Fig. 2) how the sepals, petals, and stamens are arranged in rings round the pistil as the centre.

II. The Tulip.

Examine the tulip in a similar way. There are no green sepals. The petals are *six*, and coloured. Stamens also *six*, and of equal length. The ovary is short, and contains *three* cells.

III. Comparison.

Compare the parts of the two flowers and write on the blackboard thus :—

Wall-flower.	Tulip.
Calyx = four green sepals.	*Calyx*—absent.
Corolla = four coloured petals.	*Corolla** = six coloured petals.
Stamens = six—four long and two short. (Anthers on stalks.)	*Stamens* = six of equal length. (Anthers on stalks.)
Pistil—Long. Ovary cut across shows two long cells with ovules in each.	*Pistil*—Stigma on stalk. ovary three-celled.

NOTE.—The time of two or three more lessons should be given to the general examination of other common flowers before going into a closer inspection of the anthers, ovaries, ovules, and seeds.

* The floral envelope of such flowers as the tulip is called the Perianth, and is supposed to be made up of an equal number of sepals and petals: but the children need not notice this at present.

LESSON XXX.

BIRDS' NESTS.

Illustrate with diagrams and pictures, and if possible with some specimens of nests.

I. General Appearance and Structure.

All children know something about birds'-nests, and the teacher should introduce this lesson with a series of questions leading up to the idea that birds need nests in which to deposit and hatch their eggs, and for the comfort and protection of their young. The general shape of the *lower* part of all birds' nests is that of a broad shallow basin. There are reasons for this. The eggs fall together as they are put in the nest, they do not roll about as they would be liable to do on a level floor, and they are kept close together at the bottom, so that the bird can the more easily cover them and keep them warm during the time she is "sitting."

Some birds make warmer nests than others by lining them with hair and wool, and even feathers plucked from their own breasts. There are reasons for this too. Some birds when first hatched have very little covering indeed, and these need the warmer nests. Those which live in cold countries, too, need special protection.

It is a remarkable fact that all birds of the same species construct exactly the same kind of nest. Blackbirds and thrushes line their nests with mud; but the thrush lines this again with fine grasses. Now the thrush never forgets the second lining, and the blackbird never copies the thrush. And, so far as we know, the same kinds of birds have always built their nests in precisely the same manner.

Nests are constructed of all sorts of materials—twigs, dried grass, leaves, straw, fibrous roots, moss, lichen, hair, wool, down from flowers, chips of wood, and even of fish-

bones. Large birds usually content themselves with a coarser kind of nest; but the smaller species display great art in constructing their tiny dwellings. The fowl is content to press a hollow with her body in a heap of straw, the ostrich scratches a hole in the sand, the eagle throws together a huge mass of twigs, the ring-dove is content with a few twigs interlaced, and the rooks, a little more particular, *line* their basket-work nests with root fibres.

The nests of most British birds are open above to the sky, a few only are *roofed* over. Most of them are placed on or among the branches of trees and hedgerows, a few are constructed on the ground in hollows, and some are laid at the ends of *tunnels* dug by the bird for the purpose. In other countries many nests are *suspended* from twigs and leaves.

II. Some Varieties of Nests.

(1.) *Roofed Nests.*—Of roofed nests the most common in our own country are those of the house-martin, but the neatest and the most elegant are those of the long-tailed tit. The house-martin builds her nest under the eaves of houses, where they are often very conspicuous objects. The walls are constructed of mud; and, just as the plasterer mixes hair with his mortar to make it hold together when dry, so the little bird-mason puts bits of grass, feathers, fine roots, &c., in her building-mud, and for the same purpose. The nest is lined with feathers. The door is left at the side.

The nest of the long-tailed tit is fixed in a fork where several branches are thrown off from the same point in the stem, and its situation is the thickest bush. It consists of mosses, wool, hair, and similar substances, bound together with spiders' webs and the silken cocoons of various insects. Outside it is covered with lichen, gathered from the bark of trees; inside it is lined with soft downy feathers. Some of the finches and the wren construct roofed nests, but they are not so beautiful as that of the tit.

The magpie builds a large nest, and roofs it over. The nest, which is placed in the fork of a branch high up in the tree, is a network of sticks interwoven with sharp thorns, and lined with moss, and other soft substances.

(2.) *Hanging Nests.*—These are nests hung from the ends of twigs or drooping branches, or even leaves, often over water. They are of every shape and design, but as they are all foreign, we will describe but one—the nest of the *tailor-bird.* Choosing a convenient hanging leaf, this bird pierces rows of holes along each edge, using its beak as a brad-awl. It then selects a long fibre of some plant, and passing it through the holes, draws the edges of the leaf together so as to form a kind of hollow cone with the point downwards. In this the bird constructs the nest of soft white down, gathered from plants. Should the bird fail to find a single leaf large enough, it sews two together by the edges, and should the nest require strengthening, it sews on another leaf. [The teacher may explain to the children why so many birds *suspend* their nests in hot countries. Monkeys and snakes are plentiful, and they are fond of eggs.]

(3.) *Nests in Burrows.*—The *sand-martin* makes a burrow some two or three feet deep, at the end of which to place her nest. She usually chooses a perpendicular cliff of soft sandstone. The burrow is not quite longitudinal, it slopes a little upward, so that water cannot run in. The nest is very simple—a little dry herbage and soft feathers pressed down.

The *king-fisher* takes advantage of a hole made by some other animal—usually the water-rat—in which to make its nest of *fish-bones,* ejected by the bird itself. [Explain that some birds, as the owl and king-fisher, for example, eject through the mouth the undigested parts of the food.]

The *puffin* and the *storm-petrel* can burrow, but they prefer to take advantage of the tunnel of some other animal. Many other birds take advantage of holes and hollows.

The wood-pecker makes her nest in a hole excavated with her beak in the trunk of a tree; but she always takes advantage of some spot where the wood is soft through decay. Her nest is made of the chips broken off.

LESSON XXXI.

THE HEDGE-HOG.

To be illustrated by pictures, or if possible by a live specimen.

Introduce this lesson by showing why the hedge-hog is so called. It has a snout like a pig, and it frequents, and often makes its home, in hedge-rows.

I. General Appearance and Structure.

To be gathered from the teacher's description and pictures, or from the specimen. The chief peculiarity in the structure of the hedge-hog is the spiny covering. Instead of being covered with ordinary hair, the skin of the back and sides is beset with spines. These are about an inch in length, hard and pointed, and of a dirty white colour, but marked in the middle by a dark band. The end embedded in the skin moves like the ball in a ball-and-socket joint. The under part of the body is clothed with yellowish white hair. The legs are short and feeble. There are five toes on each foot, and each toe is terminated by a claw. The tail is very short. [Compare with toes of cat and dog.] The teeth are numerous; the front molars are suitable for *cutting* purposes, and the back molars for *crushing* hard substances.

II. Habits.

We have now to inquire whether the structure of the hedge-hog is in agreement with its habits. The chief

peculiarities of structure are the *spines* and the *teeth*. Why are the spines needed? Of what special use are they? How are they used? Most animals are provided with some means of escape or defence from their foes. The hedge-hog, without its spines, would be but a feeble animal indeed. Its legs are too short and feeble for swift running, and its claws would prove but poor weapons against the fox or the badger. Hence its shield of sharp spines. When disturbed, or when attacked, the hedge-hog rolls itself into a ball, with the head and legs carefully tucked inside, from which the spines then stand out on all sides, like pins from a pin-cushion. When not in use, the spines lie flat upon the body, but the very act of rolling itself up also *erects* the spines. The organ for this purpose is a broad band of muscle, which passes along the sides, and so round the body, just beneath the skin. The contraction of this muscle draws the skin over the ball and erects the spines. This peculiar action of rolling itself into a ball, and erecting the spines, answers two purposes. It serves as sufficient protection against most of its enemies, and enables it to fall down considerable heights without injury. Very few dogs have pluck enough to make a successful attack on a rolled-up hedge-hog.

The second peculiarity lies in the teeth. Some of these are suited for *cutting* and *tearing*, and others for *crushing* hard substances. Now the hedge-hog feeds on insects, chiefly beetles, with hard wing-cases, and here the crushing teeth are needed. But it is also fond of frogs, mice, snakes, and any young game it may come across, and here its cutting teeth come into play. When in confinement it feeds readily on soaked bread and cooked vegetables. Advantage is sometimes taken of its fondness for insect food to rid kitchens of cockroaches.

The hedge-hog makes her home in forests and woods and hedge-rows, and prowls about at night in search of food. The female makes her nest of moss and leaves in cavities

under the roots of trees or in hedge-bottoms, and even in rocks and walls. Here she sleeps, with her mate, during the winter, and here she rears her young in the summer. The hedge-hog is easily tamed. It soon loses its fears, and will allow itself to be handled without attempting to roll itself up.

LESSON XXXII.

WHALE-OILS.

Specimens of train and sperm oils, and of spermaceti, raw and purified, should be provided. Also pictures of whales.

I. The Whale.

The teacher may introduce this lesson with a short sketch of the whale. He should remind the children that the whale, although it looks very much like a fish, and, like a fish, spends the whole of its time in the water, is not a fish. It suckles its young, it breathes the air, and it has warm blood; and is, therefore, quite as much a *mammal* as a cat or a cow.

There are very many different kinds of whales, large and small, and they frequent various parts of the ocean. Some, like the Greenland whale, prefer the Arctic seas; others revel in the warm seas of the tropics; a few seem to have but little choice.

All mammals have warm blood; that is, their bodies are warm like our own. Now water is a good conductor of heat, and were it not for some special provision made to prevent, the water would rob the body of so much heat as to cause the death of the animal. Hence it is that all mammals which frequent the water are provided with specially warm coverings Those which do not live entirely in the water, like the seal and the otter and the white bear, are provided

with thick warm firs. Those which spend their whole lives in the water, like the whale and the porpoise, are otherwise provided for. The skins are naked on the outside, but just underneath there is a thick layer of oily fat. [The walrus and the seals have a thin layer of oily fat in addition to the fur.] The thickness of this layer varies from five or six to twenty inches, according to the habitat of the animal. In the Greenland or right whale it is very thick, and is called *blubber*. In the sperm whale it is thinner, and has received the suggestive name of the *blanket*. Fat is a bad conductor of heat, and the layer of blubber forms a splendid covering.

It is from the layer of oily fat that the *train-oil* and *sperm-oil* of commerce is extracted.

All the *cetaceans*, viz., whale-like animals, such as the whales, dolphins, and porpoises, are furnished with a layer of oily fat; but it is only in a very few that it exists in sufficient quantity to make the capture of the animal remunerative.

II. The Whale Fishery.

The teacher will describe **how the whales are captured**, and refer to the danger of the pursuit.

Two particular kinds of whale are sought after. (1.) The Greenland whale, for its blubber and whalebone. (2.) The sperm whale, for its spermaceti and sperm-oil.

(1.) From the Greenland whale the blubber is stripped off and either boiled down and the oil extracted on board, or packed in barrels and brought home in a half-putrid state. In the latter case, on reaching port the barrels are emptied into enormous wooden vats. Here it is allowed to settle for some hours, after which the decomposing fat is run off into a copper boiler, and the separation of the crude oil is completed by the application of heat and subsequent pressure.

The blubber of a Greenland whale of moderate size will

yield from twenty to thirty tons of "train-oil," valued in the English market at about £30 per ton; and, in addition, there is the whalebone, worth perhaps from £50 to £100 more.

(2.) Spermaceti and sperm-oil are obtained from the sperm whale. This whale is distinguised by an enormous development of the head, which is half as large as the body. It serves as a kind of float to raise the nostrils above the surface of the water. The upper part of the great head is made up of great caverns, filled with an oily fluid. [Question as to *how* the head acts as a float.] When the whale is made fast to the side of the ship a hole is cut in the top of the head and the oil is drawn up, to the amount of *three to four hundred gallons*, by means of buckets. On cooling, this separates as a granular yellow solid substance—crude spermaceti, and an oily liquid—crude sperm-oil. By draining, squeezing, and then purifying, the spermaceti appears as a beautiful pearly-white wax. Mixed with some wax, spermaceti has long been used for the making of candles. It is highly prized for its beautiful appearance, and for the purity of the light produced. Except in hot countries, however, spermaceti candles have been almost entirely superseded by paraffin candles.

[Solid paraffin melts at from 110° to 150° Fah., and it softens and becomes pliable at many degrees below its melting point. Hence it is not suitable for hot climates. By more skilful preparation, and by mixture with some other substances, such as vegetable wax, &c., this defect of paraffin is now nearly overcome.]

Sperm-oil of a valuable kind is obtained from the blubber of the sperm whale as well as from the spermaceti cavity. Sperm-oil was formerly used to burn in lamps, but is now too expensive. It is used for lubricating machinery, especially the spindles of cotton-mills, for which it is superior to any other oil that can be procured.

LESSON XXXIII.

LEATHER.

Specimens of skins, and of various kinds of leather, and a piece of oak-bark will be useful for illustrating this lesson.

The varieties of leather are so many, and the processes of preparation so numerous, that it will be better for the teacher to confine his attention to the *principles* involved in the manufacture rather than to dwell on details, not of any great value, and not easily remembered by the child.

I. Structure of Skins.

Leather is made from the skins of various animals, and to enable us to understand the principle of the manufacture we must first look at the structure of the skin, and then compare its properties with those of leather. Skins are composed of two layers. All children have seen a blister on the hand. The water has separated the two layers of the skin, and the outer or *scarf-skin* is raised. After illness this skin very often peels off. You may pass a needle through it without drawing blood, or causing pain. This outer skin acts as a protector to the sensitive and delicate skin which lies below. The scarf-skin is made up of flattened cells, those near the surface being more flattened than those near the *true* skin. The cells are constantly being worn away and as constantly renewed from below. Hair grows in this skin, their roots being usually in little hollows of the true-skin, which are filled with cells of the scarf-skin.

The main substance of the true skin consists of *fibres* or *threads* interlaced and spread out to form a sheet or *tissue*, and is hence called *fibrous tissue.* This tissue when boiled in water forms *gelatine.*

Enclosed in this fibrous tissue, and filling every part of it, are nerves, and blood vessels, and fat glands. The tissue, in

fact, connects and binds these organs together. Hence it is also called *connective tissue.*

Now it is this connective or fibrous tissue only which is of use to the leather manufacturer, all the other parts of the skin have to be got rid of, and then the manufacturer has to change the tissue into another substance possessing altogether new and distinct properties. The new substance is called *Leather*, from an Anglo-Saxon word meaning *pliant, flexible,* or *easily bent.*

II. Changes necessary.

Skins, in their moist condition, readily *putrefy.* They resist decay in a dried state; but then they are *horny.* The object of the manufacturer is so to change the nature of the skins as to overcome their tendency to putrefaction, even in a moist condition; and, at the same time, to make them supple and pliant; and to increase their power to resist wear and tear.

III. Preparing the Skins.

The first object is to get rid of the scarf-skin with the hair, and the bits of flesh and fat which may be attached to the skins on the inside. For this purpose the skins are steeped for a certain time in a strong ley of slaked lime, or other alkaline solution. This dissolves, loosens, or so otherwise changes all the unnecessary parts that they may all be removed by scraping with knives. The scarf-skin and hair is then scraped off one side and the flesh and fat, &c., from the other. The lime water has its effect also on the connective tissue, causing it to swell, and become more porous; and consequently more easily permeable to the tannin solution which follows. Every trace of the lime must be removed before tanning. This is done by putting the hides in a weak solution of some acid in water.

IV. Tanning.

Oak-bark is the chief tanning substance, but others are

employed. The tannin is extracted by grinding the bark and digesting the powder in water. The prepared liquor is called *ooze*. The prepared hides are steeped in this liquor for weeks and even months, until the tannin has converted every particle of the connective tissue into the new substance *leather*. [Various processes have been invented for quicker tanning; but the leather is not so satisfactory, being harder and less supple than that prepared in the old-fashioned way.] The hides, now leather, have to be cleansed, dried and "finished."

V. Some Leathers otherwise Prepared.

Morocco-leathers are tanned with *sumach*. The best are prepared from goat-skins, the inferior from sheep-skins. The latter are split, the outer portion is used for morocco, and the inner for *wash-leather*.

Glove-leather is *tawed* instead of tanned, that is, it is preserved by means of alum and salt; then dressed with a mixture of wheat-flour and yolk of eggs, and ironed to render it supple.

Wash-leather was formerly prepared from the skins of the chamois goat, and hence called *chamois-leather*. It is now prepared from the flesh side of sheep-skins. The skins are steeped in bran-water, then wrung out slightly and sprinkled with oil, and beaten with heavy wooden hammers. The oiling and hammering is repeated, and then a few "finishing" processes bring them to the state of soft, supple leather.

As showing the great importance of the leather manufacture the teacher may refer to the import of hides and skins. Thus in 1883 there were imported, in round numbers—

Hides,	Dry,	630,000	cwt., valued at	£2,250,000
„	Wet,	560,000	„ „ „	£1,550,000
Skins,	Sheep,	8,000,000	in number, worth	£1,000,000
„	Goat,	4,700,000	„ „	£450,000

LESSON XXXIV.

THE MOLE.

To be illustrated by diagrams and pictures. A skin will be useful to show the arrangement of the hairs.

From its habits and mode of life, and the peculiar adaptation of structure, the mole is perhaps the most interesting of British mammals. Although but seldom seen alive, the results of its labours are everywhere manifest in the "molehills," which are to be found dotting the green fields all over the country. The farmer wages against it a relentless war, and many victims of the mole-catcher may be seen, during a country walk in spring or summer, suspended from the twigs of the wayside hedgerow, or the low branches of trees. Yet, as we shall see in the course of the lesson, the mole is really the farmer's friend, not his enemy.

I. Habits.

The mole lives underground, and it is but seldom that it sees the light of day. It does not simply lodge in a burrow like the rabbit; but it eats, drinks, sleeps, rears its young, and dies underground. Its food consists of earthworms and the larvæ of insects, for which it must search in the soil; and as its appetite is strikingly voracious, it must be able to move pretty quickly, or it would starve. It is necessary therefore that the body should be so formed that it can *tunnel* with the least amount of exertion; tools must be provided for making head-way, and for clearing the tunnels; and the covering must be such as to keep the wearer warm in the cold damp earth, and such that, for the sake of cleanliness, the soil shall not adhere.

Eyes such as ours would be a great disadvantage. If eyes are needed at all, they must be so placed and so protected

that not a particle of earth can get into them. Living in so dark a dwelling its sense of hearing needs to be acute to give warning of the approach of foes, and it must possess a powerful sense of smell to guide it to its prey. The mole seems to be always hungry, and seizes and devours its prey with the eagerness and ferocity of a tiger. It also drinks frequently, and, it is said, sinks wells to collect water when not otherwise easily obtained.

II. Structure.

We have now to examine the body of the mole to see how beautifully it is constructed and modelled for underground life in perpetual darkness.

(1.) It has a long cylindrical body, very short limbs, and a pointed snout. [Show how this form is adapted for making way through the soil. Compare with worm, and refer to the snout of the pig.]

(2.) Its fore-arms, hands, and claws are shaped into strong tools for scraping, digging, and shovelling away the earth. [Show this from the illustration.]

(3.) The hairs of the fur are set upright instead of lying flat on the body; and the lower portion of each hair is finer than the upper, or outer. The hair will therefore bend easily, and in any direction, without ruffling the coat. The fur is so close and warm that the mole never suffers from the chill of the damp earth; and so very smooth and glossy that the soil never adheres; and the animal whenever it leaves its tunnel is seen to be clean and smooth. The only parts of the mole which show the least trace of its labours are the bare and wrinkled paws.

(4.) The eyes are not like those of other animals. They are so completely hidden in the fur that for a long time the mole was considered to be blind. If the animal be placed in water, however, the eyes may be detected as two very small bright black beads.

(5.) The sense of sight is probably very imperfect; but not so the senses of hearing, although no external ears are visible. [The teacher will show how the ground assists the mole in hearing. We hear vehicles approaching by putting the ear on the ground, long before we can hear them through the air.] The sense of smell too is very acute, a captive mole buried in several inches of earth will instantly detect a piece of meat placed on the surface.

(6.) The teeth are formed specially for holding and tearing, and not for chewing. The upper surface of each is raised into irregular jagged points, which pierce the body of the captive so that it cannot escape.

III. Uses.

Doubtless the mole does a certain amount of mischief, for while making his tunnels he damages the roots of plants; but on the other hand he destroys a vast number of the grubs of the cockchafer, and of the skip-jack beetles which would otherwise feed on, and do much more damage to, the roots of the plants than the moles.

THE MOLE'S FORTRESS.

If we examine any one of the many "mole-hills" to be found in almost any field we shall find that it consists merely of loose earth thrown out by the mole when burrowing. They are *waste-heaps.* If we select a heap which has, under the influence of the weather, become pretty firm, and then carefully remove the material, we shall discover the perpendicular shaft out of which the earth was thrown. This shaft communicates with a burrow or tunnel, which is probably a branch from one of the permanent *high-roads* of the mole.

Could we discover one of these main roads we should find its walls smooth and firm—made so, no doubt, by the constant rubbing of the mole's body. Supposing we have discovered one of these main roads, let us follow it up. If it

is in the summer time, we may perhaps come across a large chamber lined with dried grass or blades of corn. This is the nest. We may possibly find the family at home if they are too young to travel, but otherwise the nest will be empty. The female selects a spot for its nest near where two high-roads meet, so that on the first appearance of danger the mother and her young may have a double chance of escape. This family chamber is but a simple affair. Continuing our voyage of discovery we shall in time find a more elaborate dwelling-place, which is usually called the *mole's fortress.*

Outside there is little indication of the mansion within. The hill is of considerable size, but it is placed under the roots of trees or in banks, or under thick bushes away from paths or roads, where it is sheltered and hidden from view, and where the roof is not likely to give way under the influence of the weather. The house consists of a single spherical chamber, the roof of which is about on a level with the ground *around* the hillock, and is simple enough in character; but the tunnels surrounding and leading to the chamber are somewhat intricate, and difficult to explain to children. It must be noted that, with one exception, all the burrows are *above* the chamber. First a circular tunnel or *gallery* runs round the chamber, about on a level with its roof. Then above this gallery is a second circular gallery, much smaller than the lower, and exactly over the chamber. The lower gallery communicates with the upper by five tunnels, but has no opening into the chamber. The upper gallery sends down three tunnels into the chamber. The high-roads open into the lower tunnel on all sides, like the *spokes* of a cart-wheel enter the *box.*

In forming these passages, the mole is careful that the mouth of one is never opposite to the mouth of another. Thus the openings of the high-roads into the lower gallery are not opposite to the openings of the tunnels leading to

the upper chamber; and the openings of the latter are not opposite to those of the tunnels leading down to the chamber. [In the diagram, trace the passage of the mole from one of the high-roads to the chamber.] As though this maze of tunnels was not sufficient to baffle any such enemy as the lithe-bodied weasel, it has an exit tunnel leading from the bottom of the chamber and joining one of the high-roads a little distance off.

The roof of the chamber, and the walls of the galleries and tunnels, are made quite smooth and hard by constant pressure of the mole's body. The chamber-bed, on which the animal rests and sleeps, is made of dried grass.

LESSON XXXV.

COTTON.

ARTICLES for illustration: Picture of cotton-plant, cotton-pod, raw cotton, cotton-wool; some leaves showing hairs; spiral coils of wire; specimens of goods manufactured from cotton, wool, and silk.

I. What is Cotton?

Hairs grow on various parts of plants, on stalks and leaf-stalks, and on leaves. The under surfaces of some leaves are so thickly set with hairs as to give the appearance of silvery velvet (in the silver poplar, for example). In the cotton-plant it is the *seeds* which are covered with long hairs—they grow from the skin or outer covering. The *seed-vessels* of the cotton-plant are about the size of a small walnut. Each seed-vessel contains three cells, and each cell many seeds. As they ripen, the walls of these vessels split open from the growth of the hair, which forces itself partly out of the cells, and looks like fleecy cotton-wool. The

hairs thus growing from the outer covering of the seeds of the cotton-plant, when dried, form the raw cotton of commerce. [See Fig. 9, Part I.]

II. Cotton Fibre.

All hairs of plants are made up of cells. Those of the cotton-plant are long tubes. Examined under the microscope the dried cotton hair tubes are seen to be flattened. They form tiny ribbons, thickened at the edges, with vein-like markings along the centre. The fibres are smooth and of a pearly lustre; but what is more important, in drying they have become more or less twisted, sometimes even taking the form of spiral springs. (Pea-pods twist and form similar spiral springs as they become dry.)

By experiments with some simple spiral wire show how the twisting of the cotton-fibre serves two important purposes in the manufacture of cotton-yarn. It *strengthens* the thread, because the fibres lay hold of each other; and gives a considerable amount of *elasticity*.

The value of cotton for spinning purposes depends on the length, fineness, spiral structure, and elasticity of the fibres. The fibres of the best cotton are from one and a half to two inches in length, and so fine that 1,000 placed side by side will cover but half an inch. This is "long staple," and is used for making the finest muslins and laces, and sewing cotton. The shorter fibres, from a quarter to three-quarters of an inch in length, are called "short staple," and are used in the manufacture of the coarser goods.

III. Manufacture.

The best method of giving children the most elementary notion of how the manufactured goods are produced from raw cotton is to work backwards. Take pieces of coarse material, in which the threads of the warp and woof are plainly visible—book muslin, for example—and let the children discover for themselves by examination how the threads

are interlaced. Then let them pull out a few of the threads and unravel them, to show how they are formed of a number of fibres twisted together. Here then we have two processes, *spinning* and *weaving*—*twisting* the fibres to form the thread or *yarn;* and *weaving* the yarn into cloth. An illustration of spinning may be given by twisting a thread from loose cotton-wool; and an illustration of weaving by darning a hole.

IV. Manufactured Articles.

Show specimens of as many of these as possible, and allow the children to handle them, and then compare with woollen and silk goods. Cotton goods are light, soft, and pliable, and wash well; but they are not so warm and soft as woollen or silk goods; they are, however, much cheaper.

NOTE.—For further information as to the preparation of the raw material and its manufacture, see page 78.

LESSON XXXVI.

KINDS OF ANIMALS—VERTEBRATA AND INVERTEBRATA.

(A fourth lesson in classification.)

ANY bones of vertebrates, especially portions of the back-bone, and any specimens of invertebrates, will serve to illustrate this lesson. Diagrams will also be useful.

I. Vertebrata.

In this lesson the teacher will first call attention to the fact that all the Mammals, Birds, Reptiles, and Fishes are alike in possessing an internal skeleton. We may therefore put all these classes together and call them by some name which refers to the possession of an internal skeleton.

Show specimens of a *back-bone*, one or two vertebræ of the rabbit or sheep, or the back-bone of a dried haddock—either will suffice to make clear that the main part of the internal skeleton—the back-bone—is made up of a number of pieces; and that these pieces have some power of *turning* one on the other. Now the Latin word for "to turn" is *verto*, and each little bone is hence called a *vertebra*, and the great group of animals, each individual of which possesses a back-bone made up of these *vertebræ*, is called VERTEBRATA.

Take away all the flesh from a cat, a fowl, a snake, and a herring, and we shall find in each bony skeleton one character in common; the arm and leg bones may be considerably modified, and even absent, but the *chain of bones* (many or few) running through the whole length of the body is never absent. This chain of bones, the *vertebral column*, forms and encloses a long canal which protects the *spinal cord.*

In mammals the vertebræ—take those of the sheep, for instance—are joined by pads of somewhat elastic but very strong gristle. In birds, where no motion is required in the back-bone, except in the neck, the bones are soldered together. The vertebræ of snakes are joined by beautiful *ball-and-socket* joints. [Illustrate this joint, and show how it gives great freedom of movement.] In fishes the vertebræ are *cup-shaped* at each end, and the hollow between is filled with a kind of fluid gelatine. This arrangement gives a still more perfect freedom of movement. [Illustrate with a fish-bone.]

II. Invertebrata.

The children will remember that we rejected the crab, snail, and worm from our former classes because they had no internal bones. Animals without internal bones are much more numerous than those which possess them, but of necessity they are very much smaller. [Ask why.]

A very imperfect and incomplete classification of the Invertebrates will answer our purpose.

1. MOLLUSCA—*soft-bodied.*

Includes all such animals as the oyster, limpet, whelk, periwinkle, mussel, cockle, snail, and slug. These are all well known. When removed from their shells they are found to have soft, flabby, fleshy bodies, without bone or hard skin.

The teacher will show specimens in illustration, and if he has pictures will tell the children of some of the less known forms, such as the cuttle, octopus, and squid.

2. ARTICULATA—*jointed animals.*

Look carefully at the body of a worm, a bee, or a lobster. In each case the body is made up of rings, or *segments,* jointed together. The rings are formed by the skin, which in the worms is soft and tough, but in the bee and lobster hard enough to form a kind of external skeleton. The skin between the hard rings is soft and leathery in texture, and serves as movable joints. The jointed animals exist in myriads, but we may group them in *four* great classes:—

(*a.*) *Worms* of all kinds.

(*b.*) *Insects* in which the body consists of three pieces, the middle one of which carries *three pairs* of legs, and usually *one* or *two pairs* of wings. Beetles, Butterflies, Moths, Flies of all kinds, Bees, Wasps are examples.

(*c.*) *Crustacea,* with shells like hard crusts, as the lobster, crab, prawn, and shrimp.

(*d.*) *Spiders.*

3. Belonging to neither of these two great classes of Invertebrates are the Star-fishes, Sea Anemones, Corals, and Sponges, and a host of microscopic animals which we shall not attempt to classify.

LESSON XXXVII.

THE COCKROACH.

To be illustrated by pictures, and living specimens.

There are but few children probably who have not seen the "black-beetles" which infest the underground kitchens of London and other large towns, and the teacher, as an introduction to the lesson, may ask what the children know about them. Probably their knowledge will not extend much beyond their colour and size, their nimbleness of foot when a light is introduced into the room where they are, and that they are seldom seen by daylight.

I. General Appearance and Structure.

Suppose we have captured a few—large and small. We can keep them for a few days, if provided with food and water, in a glass vessel with smooth sides. They can run up walls like a cat runs up a tree by fixing the little movable claws, with which each foot is provided, in the little roughnesses; but on the sides of smooth glass or china they find no foothold. We can therefore hold them prisoners whilst we examine them.

Before this examination, however, the teacher may ask the children how much and what they know about "black-beetles" from the simple fact that they are *insects.* We know, for instance, that there is an external skeleton of hard skin arranged in rings or segments; that the whole animal is made up of three pieces—the head, chest, and body; and that the chest carries *three pairs* of legs, and probably *one* or *two pairs* of wings. [See the preceding lesson.]

Now for the closer view. We may note, in the first place, that their colour is not black, but reddish-brown, and

it may be that one or two are light in colour. Hence the first part of the common name is not correct. They are not *black* beetles. In the second place we may note that some have large *wing-cases* covering the greater part of the body; and that others have very small cases on the sides of the chest only; while others, again, have no wing-cases at all. Those with the larger wing-cases are the perfect males; those with small cases on the chest only are the perfect females; those without any cases are the grubs and pupæ. The male insect has the second pair of wings under the first. The four wings are all of equal size, and resemble parchment. It is not often that the insect is seen to raise them in flight; but on warm summer evenings, when opportunity offers, they do fly backwards and forwards through the open windows. The female insect also possesses a second pair of wings; but they are very small indeed, and quite useless for the purpose of flight. Both *larvæ* and *pupæ* of these "black-beetles" resemble the parent, they have well-developed legs and run about and eat; but the larvæ, like other grubs and caterpillars, change the skin several times before they become perfect insects. The lighter-coloured specimens are those which have just cast the skin.

And now the teacher may show that the second part of the name "black-beetle" is a bad one. All the real beetles—male and female—when they become perfect insects have two pairs of fully-developed wings, and their pupæ never run about; in these and in other respects the "black-beetle" differs from the real beetle, and in fact is not a beetle at all. In future we will call them by their proper name—*cock-rouches*

To return to our specimens. The feelers are very long and tapering and bristle-like; and are made up of a large number of joints. The eyes are large and kidney-shaped. They are set behind the depressions from which the feelers project. The mouth is not easily seen, especially in the

female, because of a broad plate projecting from the thorax. As in all insects, the mouth opens sideways.

II. Habits.

The first interesting point in the life-history of the cockroach is the manner in which it deposits its eggs. They are not laid separately, as in most insects, but are enclosed in curious *egg-cases*, or *egg-purses*. These cases are of a reddish-brown colour, horny and hard, and oblong in form, with the edges and corners rounded off. They look very much like small roasted coffee-beans. They are slit along one of the long narrow sides, and the edges of the slit are finely toothed, the teeth of one edge fitting in between the teeth of the other edge. The eggs, *sixteen* in number, are arranged in a double row, eight on each side, like peas in a pod; and the point of each egg is opposite to a slit. The female fixes the case by means of a kind of cement in some crack or crevice, or behind shutters, or in other places of concealment. When the grubs emerge from the egg, they force themselves out through the slit between the teeth, having previously moistened and softened the cement with which they were stuck together. The newly-hatched young are at first pale in colour, but soon become darker. Before they become perfect insects they change their skins about six times.

A second interesting point in the life-history of the cockroach is its constant habit of cleansing itself. Although it emits to us a very unpleasant odour, and is seldom looked upon as adding to the cleanliness of the kitchen, yet it is a very cleanly animal. Every part of the body is brushed over with the legs continually, and then to cleanse the legs these are drawn through the jaws. Their action reminds one of a cat using its paws for cleansing.

Cockroaches are night insects. The name is a corruption of a word which means *light shunners*. They come out at night when all is quiet to feed; but on the approach of a

light they scamper away to their hiding-places. They eat scraps of meat, crumbs of bread, or bits of vegetable; and, if hard pressed, will gnaw boots or flannel or other animal substance.

When once they have found a lodgment in a house they are difficult to get rid of. Insect powder, peel of cucumber, phosphorus paste, and various traps destroy large numbers; but then the eggs, hidden away, produce a fresh supply. The hedge-hog feeds greedily on them, and is perhaps, on the whole, the best cockroach destroyer.

LESSON XXXVIII.

EARTH-WORMS.

THE teacher may have a few earth-worms in a little clear water in a glass dish.

I. General Description.

The shape, size, colour, and general outside appearance of the earth-worm are well known to all children. Let children see the specimens, call attention to the large number of narrow rings—segments, they are usually called—of which the body is formed, to the pointed head and tapering tail, and to the slime which covers the skin.

The animal has no legs, no eyes, no jaws, and it appears to have no mouth. It has a mouth, however, a wide circular opening; but it is hidden by the overlapping of the first segment. Under a magnifying glass the segments are seen to be furnished with minute bristles pointing backwards—four pairs on each segment—which the animal can withdraw within its body at pleasure. The bristles can be felt by passing the finger along the under surface of the body from the tail to the head.

The skin plays an important part in the life of the earthworm. It is the substitute for legs. When the worm is clean and healthy this skin though dense is seen to be thin and transparent, and it shows a pretty play of colours. It encloses two series of muscles, the one running from segment to segment from the head to the tail, the other forms rings round the body.

II. Habits.

From the general description the children will be able, with a little assistance, to show how beautifully the humble worm is fitted for its place in nature, and for the work it has to do.

It has to work its way *through* the soil in search of food; and its construction is such that it can do this with the least amount of labour. The cone-shaped head, the round smooth body, the muscular skin, the bristles pointing backwards, and the slimy covering, all facilitate movement through the soil.

The action of the muscles and the bristles is so interesting that the teacher may pause to describe it a little more fully. The pointed head is pushed forward between the particles of earth. In this position the front segments of the body are *fixed* by the bristles; then the hinder portion is drawn forward by the contraction of the longitudinal muscles. This action swells out the front part of the worm, and enlarges the channel it is forming. The bristles on the hinder rings now take hold of the walls of the canal, and this part being now made a fixed point the contraction of the ring muscles on the front segments forces the head forwards. By a repetition of this process the animal forces its way through substances which at first sight we should deem impossible.

Like snails and slugs, worms are more active at night than in the day time.

They feed on decayed vegetables; and swallow earth to

extract from it any vegetable matter it may contain. The residue is thrown off in the form of curiously twisted little heaps. These little heaps are very plentiful on lawns and garden paths, when the soil is moist. Gardeners know the heaps as "worm-casts;" and dislike them for the untidy appearance they give.

III. Uses.

Though humble and despised, the earth-worm is one of the most useful of all animals. The worm-casts spread over the ground serve as manure; and the myriads of tunnels bored in all directions serve for both drainage and ventilation. The surplus rain is conducted to the sub-soil, and air is conveyed to the roots of the plants.

LESSON XXXIX.

SPIDERS' THREADS.

ILLUSTRATE with pictures and diagrams.

That which interests us most in the spider family is the beautiful silky threads which the spiders draw from their bodies. In this lesson we propose to ask and to answer two questions:—How are spiders' threads formed? To what uses are they put?

I. Formation of the Threads.

Within the body of every spider there are small bags, or *glands* as they are called, which contain a thin sticky fluid. On exposure to the air this hardens and becomes tough and strong. From this fluid the spiders spin their threads. Examine the under surface of the body of a spider near the end with a lens, and you will see a bunch of little projections, probably eight in number. These are called ***spinnerets.***

Magnified very much these spinnerets are seen to be stuck all over with a multitude of extremely minute holes—the ends of horny tubes. Now the glands within the body are joined by ducts to the spinnerets; and, as the glands are contracted, the viscous fluid is forced into the spinnerets, and thence through the microscopic tubes into the air in the shape of threads of extreme fineness. The exit of the fine threads may be compared to the exit of water from the "rose" of a gardener's "watering-pot" with this difference, that in the case of the watering-pot the tiny streams of water diverge, while the fine threads of the spider converge and unite before they become solid and form the firm elastic thread with which we are all familiar. [We may note here that the spider can either unite the fibres into a single cord, or keep them separate.]

II. Uses.

Spiders spin threads for a variety of purposes.

(1.) *As dwellings.*

The Trap-door Spider makes a little tunnel, and lines it with silk; and then constructs a circular door of earth and silk mixed together, which opens on a hinge of silk. Here she resides during the daytime, and at night roams about in search of prey.

The Wolf Spider constructs an umbrella of silk among the low herbage to protect her newly hatched young; and here she tends them till they are able to take care of themselves.

The ordinary residence of the Garden Spider is a silken dome-shaped cell, built near her snare. In a cell of this kind she passes the winter.

Many spiders make tubes or cells of silk in holes and crevices. The Water Spider constructs her residence and rears her young beneath the surface of the water.

(2.) *As egg-cases.*

The female spider makes a beautiful silken cocoon in which to place her eggs. The eggs vary in number, according to the species, from about a dozen to considerably over a hundred. Some spiders carry their egg-cocoons about with them, others place them in their nests, others hide them in leaves, and holes, and crevices; by all they are carefully protected in some way or another.

(3.) *As traps and snares.*

The web of the Garden Spider is of beautiful construction, and the most perfect specimen of its kind. It is nearly circular, and constructed of a number of straight lines diverging from a common centre, with a spiral line wound regularly upon them. [The teacher can illustrate the formation by a sketch on the blackboard. See Fig. 5, Appendix.]

(*a.*) The outer or *foundation* lines are first laid. These are attached to certain available points, and then carried to other points, sometimes by the spider descending to the ground walking across and then ascending; and sometimes by the spider emitting a thread, and allowing the wind to carry it across. These lines are very firm and strong.

(*b.*) The *radiating* lines are next fixed. These lines are all simple smooth threads not very elastic. They are stretched from the foundation lines, and meet in the centre of the future snare.

(*c.*) Starting from the centre the spider proceeds to stretch a series of short threads between the radii following a spiral course. The first few turns consist of smooth threads like the radii; but then the rest are of a different kind, very elastic, and covered with thousands of tiny beads of a very sticky fluid. The construction of the whole takes about an hour, and the sticky thread appears to be renewed daily. [The teacher should elicit from the children the advantages of the elastic thread, and the sticky beads in seizing and holding prey.]

The spider forms this web by the sense of touch, and not by that of sight. The eyes are placed on the top of the head and the spinnerets under the body near the extremity, so that the animal is unable to see the thread as it is formed. A careful observer will note that the thread is always guided by one of the hinder legs.

This spider makes a further curious use of its silk. When a fly gets entangled in the web, the spider rushes from her hiding-place, seizes her prisoner, and binds it with cords. This she accomplishes by turning it round and round with her fore-feet, at the same time pouring out an abundant supply of silk from her spinnerets.

(4.) *Other uses.*

Spiders constantly employ their silken threads as safeguards against falling, when wishing to descend from one place to another. Some of them construct bridges between elevated points.

The formation of one of these silken bridges is a curious process. The spider faces the wind, attaches a thread to her resting place, and then elevates the hinder part of her body as far as possible. The wind catches the short thread thus produced, and draws it out in the form of a loop, which, gradually increasing in length, floats away until it comes in contact with some solid body to which it clings. To complete the bridge the spider draws the line tight, and fastens the end.

"Some spiders possess the remarkable faculty of shooting out threads in diverging lines into the air, which, being lighter than the atmosphere, form a sort of balloon, on which the little aëronaut mounts above this lower world, and rides at will among the clouds." *

* Prof. Rymer Jones.

LESSON XL.

BLEACHING.

Articles for illustration: Bleaching powder, oil of vitriol, basins of water, coloured calico and silk, with sulphur.

I. Cotton and Linen.

Have two large basins on the table nearly filled with water. Into the first throw three or four ounces of bleaching powder—chloride of lime—and into the other a few drops of oil of vitriol—sulphuric acid. Immerse in the first basin a piece of coloured calico, and allow it to remain a few minutes in the mixture. Occupy these few minutes in explaining the nature of the bleaching powder. A noxious gas called chlorine is passed through slaked lime. The lime absorbs the gas, and becomes chloride of lime, or bleaching powder. The characteristic smell of the powder is not easily forgotten. The chlorine is the active agent in bleaching. A little of the gas escapes when the powder is exposed to the air, but most of it is combined with the lime—locked up in the lime, we may say—and the calico is not bleached till the gas is set free.

Now immerse the calico in the second vessel, containing the dilute solution of oil of vitriol. The acid takes the place of the chlorine in the bleaching powder, and the liberated gas quickly removes a portion of the colour. To remove all the colour we must wash in soda-water, and then repeat the process.

The cloth must be well washed and even boiled in plenty of water to remove the last trace of the acid, which would otherwise destroy the fabric. *This is but a rough illustration of "bleaching."*

Bleaching, in the manufactures, applies almost solely to the removal of the light-brownish or grey colour of newly-

woven cotton and linen goods, either for the market or for the dyer. We may sum up the process as *cleansing, removing the colour, cleansing, stiffening.*

The *cleansing* is done by means of solutions of slaked lime, soda, and weak acid.

The *colour is removed* by bleaching powder and oil of vitriol. The *stiffening* is produced by passing the cloth through a solution of starch, or British gum. [Rub a piece of calico, the stiffening comes out as a powder.]

Compare a garment made of new unbleached calico with another made of the same kind of material, but which has been washed and dried in the air and sunshine many times. The latter has become bleached, and can scarcely be distinguished from the bleached goods. Practically this was the old method of bleaching, and to some extent this method of bleaching in the air is still used in the bleaching of linen.

II. Silk and Wool.

Chlorine gas is not suitable for bleaching silk and wool, because it destroys the fabric; and another method is followed. The agent again is a noxious, suffocating gas, well known to children in the fumes of burning sulphur.

To illustrate the process, the teacher has only to hold a piece of coloured silk, or a red rose, (damp) in the fumes of burning sulphur. [If the teacher has the apparatus at his disposal for making and collecting the gas, sulphurous acid, in a bottle, the process can be better demonstrated.] The sulphur must he removed from the room as soon as possible, as when breathed it produces violent coughing.

Unlike chlorine, the sulphur fumes do not *destroy* the colour, for if the silk or flower be held in a bottle of ammonia gas, the colour is partially restored. In a similar fashion the natural colour of flannel soon returns after washing, the agent being the soda in the soap. The process of bleaching silk and wool ready for the market, or for the dyer,

broadly speaking, consists of cleansing and removing the colour by sulphurous acid gas. Wool is cleansed by heating in water [to about 90°], to which some substance containing a little ammonia has been added, and then rinsing. Silk is cleansed by boiling in soap and water, and rinsing in pure water. *Straw* for straw-plait is also bleached in sulphur fumes.

NOTE.—The principles involved in dyeing may be illustrated in another lesson. For subject matter, see page 90.

LESSON XLI.

THE RAT AND HIS RELATIVES

ARTICLES for illustration: Skull of rabbit for teeth, and any specimens of the furs; also pictures of Rodents.

Most children will have seen a rabbit, a rat, a mouse, or a squirrel in the act of feeding, and may possibly have noticed the large front teeth with which these animals *gnaw*. Now all animals in the world—and there are an immense number—which have *four* large front teeth suitable for *gnawing*, like the rat or the rabbit, are included in one great *group* and called *rodents*, viz. gnawing animals. The *hares*, *rabbits*, *squirrels*, *rats*, *mice*, *dormice*, and the *voles* are chief members of the group living in this country. Their chief foreign relatives are the *beavers*, *squirrels*, *prairie dogs*, *marmots*, *hamsters*, *lemmings*, *jerboas*, *porcupines*, and the *chinchillas*. Of all these rodents the rabbits and hares are the only members which are used as food to any great extent; but many of them are very valuable for their furs.

I. Teeth of Rodents.

The rodents may and do differ very much in other par-

ticulars, but in the structure and use of the teeth they are all alike. The teacher will no doubt be able to show the teeth, if not in the living animal, at least in the skull and jaws of a rabbit. The teeth are of two kinds only, the *grinders* and the *cutters*.

The surface of the *grinders* presents a rasp-like appearance, from the plates of enamel, which stand up in ridges above the softer dentine.

The *cutters*, or *incisors*, are *four* in number, *two* above and *two* below. They are strong, sharp *chisels*. Mice can gnaw through boards, rats have been known to cut through leaden pipes, and beavers cut down trees. Unless some special provision were made, teeth used in this way would soon get blunt and useless. To prevent this, the outer or front surface of each tooth is covered with a thin plate of very hard enamel, while the other part of the tooth is made of bony matter, and is much softer. As the tooth is used the bony matter wears away more quickly than the enamel, and the latter is left as a thin cutting edge. [The teacher should show how the chisel and plane are constructed on this plan. Steel and iron corresponding respectively with the enamel and bone.] Yet another provision is necessary. The carpenter's chisel wears away in time, and so would the rodent's tooth; but for the fact that just as fast as it is worn away above, it grows and is pushed up from below.

It is necessary also for the purpose of gnawing that the lower jaw should be so jointed to the upper as to allow of motion *backwards* and *forwards*. [Compare the motion of jaws of cat and horse.] The food, cut into slices with the front teeth, has to be ground with the molars; hence the jaws have a second, a *grinding* motion, like the cow or the horse.

II. Other Common Features.

All rodents have *feelers* in the shape of whiskers, like the

cat. [Question on, and point out their uses.] The feet usually have *five* toes, armed with claws, some of which are sharp, curved, and pointed for climbing, and others blunt and strong for burrowing. The number of toes is sometimes reduced to *four*, or even *three*, on the hinder limbs. In the mouse family there are *four* toes on the front leg, and *five* behind. In the great majority the fore-paws are used to some extent as hands. [Instance squirrel with nut.] The majority of the rodents are nocturnal, and burrowing animals; and many of them hibernate.

III. Special Points in Structure or Habit.

(1.) *Rat.*—The foot of the rat is jointed so loosely to the hind limbs that it can be turned half-way round, and the claws pointed backwards. [Show how this assists the animal to descend perpendicular walls, &c.]

(2.) *Harvest Mouse.*—This, the smallest of British quadrupeds, in addition to specially long, flexible toes, has a prehensile tail. She climbs grass and corn stalks with facility. In descending she twists her tail round the stem and *slides* rapidly to the ground. This mouse builds a very pretty nest about the size of a cricket ball, and suspends it from stout grass, or other stems.

(3.) *Flying Squirrel* (so called).—These squirrels have a fold of the skin stretched along the sides of the body, and attached to the legs almost to the feet. When the squirrels take their long flying leaps this skin is stretched to its utmost extent and gives considerable support in the air. [Compare with an open umbrella pulled against the wind.]

(4.) *Beavers* have the toes of the hind feet webbed, and converted into paddles, for swimming purposes. The tail is large and scaly, and flattened above and below. [The teacher may describe the most striking peculiarity in the habits of the beavers—the construction of dams.]

(5.) The *Jerboas*, and the American *Jumping Mice*, have long

and strong hind legs and feet, on which alone they travel, like the kangaroo.

(6.) In the *porcupine* long spines take the place of ordinary hair.

IV. Uses.

Rabbits and hares form an important article of food in some countries; but the rodents are most valuable for their fine warm furs, and millions are destroyed every year to supply the market. The most valuable skins are those of the squirrel, rabbit, hare, musk-rat, beaver, chinchilla, and hamster. (See page 132.)

LESSON XLII.

BEAKS OF BIRDS.

FOR illustration: The head of a duck, any other specimens of beaks. Pictures of birds' heads, especially that of woodpecker.

I. Introduction.

The jaws of birds are neither furnished with teeth on the inside nor lips on the outside; but are covered with a horny substance resembling the nails of our fingers. The *beaks*, or *bills*, of birds form a very striking illustration of the adaptation of structure to habit. Thus birds of prey feed on flesh, and their beaks are strong, hooked, and pointed; just fitted, in fact, for the work they have to do. Parrots feed on nuts, and the beak is constructed for crushing the shells and for picking out the kernel. Herons and storks feed on fish, which they catch while standing in the water, and their beaks are long, pointed, and sharp, and fitted for stabbing. Sparrows feed on hard seeds, and the beak is short, strong, and hard, and so on. Most of these and similar illustrations may

be gathered from the children; and we propose in this lesson to take two examples, the *duck* and the *woodpecker*, for special illustration.

II. The Duck.

Let the children examine the duck's head. Call special attention to the shape of the beak. It is flat and broad. Open the jaws—*mandibles*—and point out the comb-like fringes along the margin of the upper mandible. There are some fifty or sixty teeth-like projections on either side. They are longest in the middle and become very short at either end, and are so set that the fine tips point backwards. Next show how the edges of the lower mandible are turned up in a sort of fold, and that on the outside of this fold is set a row of grooves into which the comb-like teeth of the upper mandible fit.

Now look at the tongue. It is large and fleshy, and more like the human tongue than that of any other bird. The sides are furnished with fringes softer and more fleshy than those of the beak; and the teacher may tell the children that these fringes, and the tongue itself, are abundantly furnished with nerves, giving a delicate sense of touch to the whole organ.

The meaning of this special arrangement of the beak and tongue is easily seen if we watch the duck searching for food in its natural element. Ducks find their food in the water, and more especially in the soft mud beneath, where it cannot be seen. The beak is plunged in and rapidly opened and shut; the comb-like fringes act as a filter, and the water is strained off, while the delicate, sensitive tongue selects, by *feeling* alone, whatever is fit for food in the residue.

III. The Woodpecker.

The structure of the beak and tongue of the woodpecker is widely different from that of the duck. This bird

feeds entirely on insects, or their grubs, which locate themselves under the bark of trees, or in the unsound wood beneath. It must of necessity, therefore, break away the bark, or bore holes, to get access to its prey. Therefore its beak, instead of being broad and soft, is narrow, and straight, and hard, and sharply pointed. But the most curious part of the apparatus of the mouth is the tongue. "On opening the beak of a woodpecker immediately after it has been killed, the tongue seems of ordinary length, or indeed rather short, and shaped somewhat like a spear, pointed at the end and barbed. [See page 162.] This, however, is only the tip of the tongue. The whole drawn out looks like a long earth-worm; and the bird has the power of extending this tongue to a great distance beyond the beak."

Watch the bird at work. It runs over the tree-trunk, tapping here and there with its beak, till it comes to a spot where its instinct tells it that insects are beneath. It then sets to work to break away the bark with its powerful beak, and expose the insects in their snug retreat. Suddenly it darts out its tongue, spears its prey, and carries it instantly to its mouth. [Compare with tongue action of chameleon, page 164.]

LESSON XLIII.

SNAKES. I.

ILLUSTRATE by diagrams and pictures. Show a ball-and-socket joint if possible.

I. Introduction.

The word snake means *creep*, and this exactly expresses the gliding, graceful motion of this animal over the surface

of the ground. The body is long and cylindrical in shape, tapering in the tail portion, and very *flexible* in every part.

It seems at first sight that the snake is a very helpless creature without legs or feet; but a closer inspection into its habits will show that this is far from being the case. Without legs it moves so swiftly as not to be easily captured, without fins or a broad tail it swims well, and without hands or claws some kinds can climb the perpendicular trunks of trees, or dart from branch to branch like monkeys.

II. The Skeleton. (Internal and external.)

To understand how the snake does all this we must look at the bony skeleton inside and the scaly covering outside; for the ribs and scales in the snakes are the organs of locomotion.

Show from the diagram that the internal skeleton consists of a large number of vertebræ, with a pair of ribs joined to each, except the tail vertebræ. The vertebræ are joined by ball-and-socket joints, which allow of great freedom of motion. (Illustrate and compare ball-and-socket joint of shoulder with elbow-joint.) But the most striking modification of the structure of the skeleton lies in the ribs. Each pair of ribs compasses about three-fourths of the body, and they are all jointed to the vertebræ by ball-and-socket joints, while at the opposite ends they are free. By this arrangement each rib can be moved backwards and forwards as a leg with great freedom. The external skeleton consists of scales overlapping, like the tiles of a house, the hinder edge being free. The scales on the under surface of the body are larger than those on the upper; they in fact very often form a single row of half bands as far as the tail Under the tail there is a double row of these scales.

How does the snake use the ribs and scales in locomotion, climbing, &c.? The free ends of the ribs are attached by muscles to the broad plates of the under surface of the body,

and it is by the joint action of the ribs, scales, and connecting muscles that the snake may be said to walk. By means of the ribs the scales can be pressed forward and then drawn back; but as they are drawn back the free edges hitch in any inequality of the surface, and the creature is drawn forward with a quick, gliding movement. A sharp eye may detect the very movable ribs acting like so many legs. It follows from what has been said that a snake is unable to creep over a smooth surface, like a sheet of glass.

III. The Mouth.

Snakes feed on living prey, which they capture for themselves. The common Ringed Snake of our own country feeds mainly on frogs; the Viper, another snake found in some parts of England, feeds on mice and small birds. The larger snakes of hot countries capture much larger animals. Now, if we examine the mouth of a snake, we shall find no teeth fit for tearing flesh, like those of the cat, or for grinding, like those of the horse. Such teeth as there are, are small, conical, and sharp, and their points are all turned backwards. Such teeth as these are useful for *holding*, but unsuitable for mastication, and the prey must be swallowed whole.

Now the second striking peculiarity in the structure of snakes is the special provision made whereby they can swallow animals whole which are much larger in diameter than themselves. With the exception of the lower jaw all the bones of our heads are fixed. In the snakes the arrangement is different; the bones of the lower jaw are *free* in front, so that they can be widely separated; those of the upper are united by an *elastic* membrane instead of by bone, while those of both jaws are united to the bones behind by similar elastic membranes. When necessary, therefore, all these bones can be widely separated, enlarging the cavity of its mouth to many times its ordinary size. But the enlargement of the mouth is not sufficient, the prey has to be forced

down the throat and into the body. We can easily understand how the walls of the throat (gullet) and the skin of the body can be sufficiently elastic, but the prey has to pass along between the ribs. And here come in again the beautiful ball-and-socket joints of the ribs. Had the joints been hinge joints they would have sufficed for locomotion only, but admitting of no motion outwards and inwards the prey could not have been swallowed. The ribs open outwards for the prey to pass, like the legs of a pair of "dividers."

There is one other point in the process of swallowing by the snake, which is different from that of most other animals. Our food after mastication is passed to the back of the tongue, where it is seized and carried backwards by the muscles of the throat; but in snakes the latter operation is performed by the two halves of the lower jaw. These are *alternately* pushed forward and drawn back. One jaw holds the prey with the pointed teeth, while the other jaw takes a fresh hold. The action may be illustrated by a boy in a fixed position pulling a load towards him by means of a rope hand over hand.

LESSON XLIV.

SNAKES. II.

EITHER a living or a dead specimen will be of immense advantage for this lesson. Pictures of snakes also should be provided.

I. Introduction.

Reptiles are generally looked upon by most people with dread and dislike; but of all animals snakes are viewed with the greatest horror. This doubtless arises from the stealthy and silent manner in which they usually approach their victims, from the terrible poison fangs with which many of

them are armed, and from the fact that often the first indication of their presence is the fatal bite.

We may divide the snake family into two great divisions, *poisonous* and *non-poisonous*. In this country we have a representative of each division, the Viper or Adder, and the common Harmless Snake.

"A little snake, with rows of black spots on the back and sides, a yellow splash behind the head, and pale lead or bluish underneath, may be seen now and then in quiet, warm places in England basking on banks in the sun or sliding in and out of a pond. It is often made a pet of, and is harmless to man, although a terror to frogs; but even to them it is not poisonous; it is the common Harmless Snake. Another one, found on dry heaths and sandy banks, and amongst low brushwood and thickets, has the neck rather smaller than the back of the head, which is enlarged behind the eyes, and the long body swells to about its middle and then scarcely diminishes in thickness to near the end, where it becomes abruptly smaller. Its colour may be olive, or rich deep brown, or dirty brown-yellow, and there is a zig-zag pattern down the sides, and spots of a darker tint. This is the Viper or Adder, and it inflicts fatal wounds with its fangs on small animals, like mice; and its poison will imperil the life of a delicate, unhealthy man. Common observation can thus separate the snakes of our country—for these are the only two—into two divisions, the poisonous and the non-poisonous, and this classification holds good for the snakes of the whole world." *

II. The Viper and the Common Snake.

As the Viper is the only English snake to be feared we will examine it a little more closely. Children should be able to distinguish it from the Common Snake at first sight. In the first place, it never attains so great a length as the

* "Cassell's Natural History."

common snake, eighteen or twenty inches being seldom exceeded. Then, looking down upon it, the head appears to be flattened and somewhat triangular in shape. The ground-colour of the scales varies; but the head always carries two uneven black lines, meeting in front, and the back shows a row of square black patches, placed corner to corner, zig-zag fashion, something like the diagonal line of black squares across a chess-board.

The Harmless Snake may be known by the absence of the peculiar black markings on the head and back of the Viper; but its slender, tapering head, the yellow patches on the neck, and the black spots scattered on the back and sides, are its positive distinguishing marks. The Viper frequents open woodlands, dry heaths, and sandy wastes; the Common Snake prefers the neighbourhood of ponds, where it can more readily obtain its food. Both snakes and vipers hibernate; they assemble in numbers in some secure retreat, and, with bodies intertwined, sleep the cold winter away.

III. Poisonous Fangs.

The poison of the Viper, and other poisonous snakes, is secreted in a pair of glands, one on each side of the back of the head (refer to our salivary glands), and is stored up in two sacs for use when wanted. The fangs are simply two fine, long, movable teeth in the upper jaw. When the mouth is shut these fangs lie along a fold in the gum; but, when the animal opens its mouth to strike, the fangs become erect. The fangs themselves are not poisonous, but they introduce the poison into the bite; they are hollow, and the poison is passed from the poison-bag through a tube to the base of the fang, whence it passes through the canal of the tooth. Should a snake lose one of these fangs, which is not infrequently the case, another grows in its place; in fact there are always one or more partially grown fangs behind those fit for use.

The long, forked tongue of snakes is perfectly harmless; it is merely an organ of feeling.

IV. Other Snakes.

By far the greater number of snakes are *ground* snakes; but in tropical countries many snakes pass their lives in trees, climbing from branch to branch with wonderful ease and dexterity. They are usually very long and slender, so much so that some are called *Whip*-snakes. Some of the *Tree*-snakes are poisonous. A few snakes live in burrows underground, and some live in water. The fresh-water snakes are all harmless; the sea-snakes are all poisonous. The teacher may further illustrate this lesson by reference to any of the foreign poisonous snakes, such as the Cobra and Rattlesnake; and to the enormous but non-poisonous Boas and Pythons, which crush their victims to death.

LESSON XLV.

FISHES. I.

Illustrate with pictures, a dead specimen, and, if possible, a live specimen in water—a gold fish, for instance.

I. Introduction.

Fishes are inhabitants of the water, either fresh water or salt. Here they are born, here they live, and here they die. They are not, however, scattered without order or arrangement; on the contrary, just as in the case of land animals, their instincts lead them to make a home in that part best adapted to their well-being. Some live near the surface of the ocean, others never quit the depths; some revel on the sandy floor, others grovel in the ooze and mud; some never quit the salt water, others spend a portion of their time in

the waters of rivers; some are altogether fresh-water fish. We find similar habits of life, too, in the water as on land; some fish live in solitude, others in shoals; some occupy the same locality all the year; others in vast numbers migrate from one part to another.

The typical form of a fish is well known, but we find other and curious shapes. Some fish are round as globes, others are flat as boards; some are as broad as long, others are long and thin, with scarcely a difference in thickness throughout.

The body is usually covered with scales, and these are of all shapes, sizes, and colours. They vary in size from a point to a plate; and in colour from the dullest shades to the brightest hues of the rainbow.

Fishes feed on succulent marine vegetables, on worms and shell fish, but mostly they devour other fish. In the sea might is right; the great ones eat the small, and the strong devour the weak. They have no respect for even their own kindred.

It will be impossible for us to consider the variations in form and structure of the vast multitude of fishes. It will be sufficient for us to take a common example—the Herring, Codfish, or Mackerel—to show how beautifully fishes are fitted for the watery element in which they live. We shall first ask and answer four questions—*How do fishes move? How are they protected? How do they breathe?* and *How do they feed?* And it will be convenient to answer the first two in this lesson.

II. How do Fishes move?

(1.) *Shape of Body* (say the herring).

By actual experiment in a vessel of water show that one *form* of body can be moved more easily through the water than another. Take a cone or a wedge of wood, for example, and pass through the water, first with the base forward and

then with the point or edge. Show next that the body of the fish is shaped something like a pair of wedges set back to back, the hinder one coming almost to a point, but with the edges pared off. Refer to the shapes of boats, and elicit why they are so shaped, and generally lead up to the proposition, that the body of the fish is so shaped that it can be moved through the water with the least possible amount of force. [See Fig. 2, Appendix.]

(2.) *The Tail and Fins.*

If the teacher has a living specimen the attention of the children should be drawn to the graceful sweep of the hinder half of the body and the tail from side to side, and the consequent motion forwards. If not, he may refer to the way in which a boatman propels his boat with a single oar placed over the stern of the boat. The boatman imitates the fish in this use of the scull.

The fins vary in number and position, but most fishes have *five* kinds. They may all be seen on the herring, though they are small in size. Just behind the head there is one pair; these correspond to the fore-limbs of mammals, and are called *Pectoral,* viz. Breast fins. A second pair corresponds with the hind-limbs. These are the *Ventral,* viz. Belly fins. In some fishes these are placed as far back as the tail, in others as far forward as the throat. Besides the Caudal or Tail fin, there are other fins placed perpendicularly along the upper and lower sides of the body. These are the Dorsal and Anal fins. With the exception of the Caudal fin, the chief use of the fins is for *balancing.* Cut off the fins and the fish rolls over on to its flat side. The fins are merely folds of the skin spread out, and strengthened and supported by bony spikes.

III. The Covering of Fishes.

The general covering of mammals is *hair,* that of birds *feathers,* that of fishes consists of *scales.* The teacher will

show the scales of the herring, or that of any other fish he may have secured. He will call attention to the way in which they are arranged on the body, how they overlap like tiles on a house, but from head to tail instead of from above downwards. He will compare the fastenings with those of tiles. Tiles are fixed by pegs near the upper edge. The front edges of scales are embedded and held firmly in folds of the skin. The fishmonger, to remove the scales, scrapes his knife from the tail to the head. By this means the knife gets under the free edge of the scales, and forces them off. The scales form a beautiful protecting skeleton, and at the same time admit of perfect freedom of motion. The slimy covering over the scales will next be brought under notice, with the purpose it serves; and lastly, the teacher may deal with any modifications in the scaly skeleton as time and opportunity offer.

LESSON XLVI.

FISHES. II.

FISH can be obtained without difficulty for illustrating this lesson.

IV. How they breathe.

Explain to the children first of all what is the real essence and object of breathing, viz. getting fresh air in contact with vessels containing the blood, so that the oxygen may get in through the walls, and the impure air may come out. The blood must thus be cleansed, or the animal dies. The larger land animals take air into *lungs* or *sacs*, the walls of which are covered with blood-vessels, and the exchange of pure for impure air is thus made. But fishes living beneath the surface of the water cannot make the exchange in this

way. All natural water contains a certain amount of air, and it is this air which the fish has to take out. When water is boiled this air is driven out, and if a fish be placed in water lately boiled, it turns over on its side and dies without a struggle. Its blood-vessels are arranged on a bunch of leaflets placed on each side of the head—the gills; and over these gills the water is constantly flowing. The gills may be called the lungs of fishes, because they have to serve the same purposes.

Show the gills of the herring. They look like fringes. Under the microscope they are seen to be full of thin-walled blood-vessels. As the water flows over these blood-tubes, sufficient air passes through the thin walls from the water to the blood to keep the latter pure. Of course, at the same time the impure air escapes into the water. When a fish is taken from the water the gills shrink and fall together, and become dry; and the fish dies because its gills cannot do their work. The fish is, in fact, suffocated for want of air, just as much as a mouse would be suffocated if held under water. Both die for want of the necessary air.

If we watch a fish we see that it appears to be constantly drinking. This is not so, however. The water, it is true, is taken into the mouth, but it is passed back over the gills and out through holes at the sides. The throat is closed meanwhile, and no water enters the stomach.

V. How Fishes feed.

To learn how fishes feed we may look at the mouth, the teeth, the tongue, and the lips. The lips are horny, and hence there can be little or no sense of feeling. The tongue is almost immovable, and often bony or beset with bony plates, hence the sense of taste can be but slight. The teeth are very variable in number, form, and position; but for the most part they are simple conical spikes with the points bent backwards towards the throat. These teeth are suitable for

seizing and holding, and not for chewing. We may learn, therefore, by a simple inspection of the mouth, that fishes mostly catch their prey alive, and swallow it whole.

VI. Specimen Fish.

The teacher should now direct attention to any peculiarities in structure and habit of such common fish as are within his reach. We take two illustrations, the Plaice and Eel.

(1.) *Plaice.*

Most people imagine that the dark side of a *flat* fish is the back and the light side the belly; but really these fish are compressed sideways like the herring, only to a greater extent. Then both eyes are on the dark side, but when quite young the eyes were on both sides. As the animal grows, one eye works round to the same side as the other. If we could look at the plaice at home these peculiarities in structure would be explained at once. Flat fishes spend much of their time either resting on, or partially covered by, the sand or mud at the bottom of the water; and the colour of the fish so much resembles the floor on which it rests that it is not easily distinguished. Again, resting on the mud or sand, an eye on the lower side would be worse than useless. Dorsal and ventral fins extend quite along the body of the plaice from head to tail. The scales are very small, and so are the teeth. The principal flat fish used as food are the Plaice, Soles, and Turbot.

(2.) *Eels.*

This fish takes the shape of a snake. It looks and feels as if it had no scales. It has, however, a vast quantity, though so small as to be almost invisible. Eels are very slimy fish, and difficult to hold. The chief peculiarity in the eels, besides their shape, is the arrangement of the gills. Instead of the opening of the gills for the exit of water being close at hand, it is placed far back, and consists of but a small hole. When this hole is closed the fish can keep its gills

moist for some time, and thus live out of water. In fact it occasionally happens that when one piece of water is pretty well dried up eels migrate to another place, creeping over the ground like snakes. Eels pass the winter in a torpid state in the mud.

LESSON XLVII.

INSECTS. I.

(General form and structure.)

THIS lesson should be illustrated with diagrams and with specimen if possible. A piece of India-rubber pipe with iron wire coiled in interior to illustrate the breathing tubes will be useful.

I. Why so called. The chief Organs.

Show from the illustration or specimen that the body appears to be *cut into* in two places giving three natural divisions to the body. Hence the name insect—*cut into.*

The *head* carries the *mouth* apparatus, the *eyes,* and the *feelers.*

The *chest* (or thorax) carries *three pair* of legs below and *two pair* of wings above.

The *body* (or abdomen) sometimes carries a *sting;* and sometimes a special organ for *boring,* and then *conveying eggs* into the holes.

II. Segments and Joints.

Call attention to the rings of the body. Refer to lesson on classification. Insects belong to the great subdivision of the boneless animals, which have the skin divided into rings or segments. Insects usually have *nine* segments in the body, and *three* in the chest, and the head forms *one* piece. But all these segments are not always distinguishable except

with the aid of a magnifying glass. They may, however, be clearly seen in the caterpillar, and the body segments are fairly distinct in most butterflies, moths, ants, bees, and flies.

The segments are formed of hardened skin, but the skin between the segments and which connects them is not hardened; it is pliant, tough, and elastic, and answers the purpose of ball-and-socket joints. The segments themselves are not perfect rings. Each consists of two half-bands—an upper and a lower—joined by the pliant, elastic skin. This arrangement gives considerable freedom of movement. [See Fig. 4, Appendix.]

III The Head.

The head carries the apparatus of the mouth, the eyes, and the feelers.* The structure of the *mouth* varies of course with the kind of food on which the insect feeds, but in one particular they all agree: when jaws are present they always open sideways, and not up and down like our own. There may be several pairs of jaws one behind the other; some are formed for cutting and tearing, others for crushing, and some have the edges toothed like a saw. Some insects have trunks instead of jaws through which they suck juices—it may be nectar of flowers, or the blood of other animals.

The *eyes* are not single like those of vertebrate animals; but each eye consists of a large bunch of very small eyes. Each eye may thus be made up of thousands of small eyes. They usually stand well out from the head so that the insect may see in every direction—above, below, beside, before, behind.

The *feelers*, one on either side of the head, are of various forms, shapes, and sizes. That they are of great service to the insect is quite certain, for the animal cannot live

* The mouth-apparatus, the eyes and the feelers should each form the subject of separate lessons.

long without them; but of their exact use we are ignorant. They may be organs of feeling, scent, or hearing.

IV. The Chest.

The chest carries the *legs* and *wings*. The legs are always *six* in number. [See Lesson L., on Legs and Feet.] The *wings* are usually *two pairs*. Very often, as in the beetles, the front pair are hardened, and used to *protect* the second pair, and not for flight. In some of the flies the second pair is wanting, but their place is marked by two little stalks with knobs at the ends. *Balancers* they have been called, because it seems they act as balancers during flight, and the insect cannot fly without them. In a few insects the wings are entirely wanting. Some of the ants shed their wings after a certain period.

V. The Body.

The segments are usually distinct in the body. In those insects whose front pair of hardened wings covers the upper surface of the body, the segments are solid below only and not above. The wing-cases, in fact, do the duty of the hardened skin.

A close examination between the segments, and between the upper and lower half of the same segment, will discover a number of small holes on either side; these are the ends of fine tubes, which communicate with two larger trunks running along each side of the body. From these main tubes other and smaller tubes branch off, and these again send off smaller tubes which traverse every part of the body. These tubes are prevented from collapsing, or falling together, by a kind of *elastic* spring coiled up closely between the two membranes of which the tubes are built up. [Refer to the India-rubber gas-pipe kept expanded by an iron wire coiled up inside.] These tubes are the breathing organs of the insect. It has no provision by which the blood is brought to one particular part for cleansing, and so the air is taken to the

blood-vessels in every part of the body. By this beautiful arrangement not only is the insect endowed in proportion to its size with life, vitality, and strength beyond all other animals; but its weight is reduced to the extreme limit.

LESSON XLVIII.

INSECTS. II.

(Chief kinds. Benefits and injuries.)

ILLUSTRATE with drawings and specimens.

I. Kinds of Insects.

The teacher may ask for the names of insects, and make a rough classification by a method similar to that used in Lesson XXIV.

Insects are usually grouped according to the structure, arrangement, and number of the wings. The following may be taken as *types* of the chief groups, and the attention of the children should be drawn to the structure of the wings, either by drawings or specimens. Beetle, earwig, grasshopper, dragon-fly, bee, butterfly, and house-fly.

1. *Shield-winged.*

In the beetles the first pair of wings are horny, or leathery, in texture. They form a pair of folding shutters, and serve as a *shield* to protect the second pair, which are folded crosswise, and packed away beneath. The hinder pair are much larger than the front pair, and alone are used as organs of flight. This group includes all the beetles, of which eighty thousand of different kinds have been described. Very much like the beetles are the earwigs, but their wing-cases are smaller and softer, and the flight-wings being large have

to be folded very carefully so that they may be quite covered by the cases.

The earwigs are sometimes put in a group by themselves and called by a long name which means *beautifully folded.* Contrary to the usual habit of insects, the earwigs take great care of their young.

2. *Straight-winged.*

The grasshopper has wing-cases like the beetle, but they are thinner, and show a net-work of veins; and instead of folding straight down the back they *over-lap.* The hind wings are folded lengthwise, and *straight,* like a fan; hence the members of this group, which includes cockroaches, crickets, and locusts, are called *straight-winged.*

3. *Lace-winged.*

The wings of the beautiful dragon-fly are all used for the purpose of flight. They are transparent, and so full of veins that they look like delicate lace, hence the name *lace-winged.* The may-flies, which live but for one day, and the *white* ants belong to this group. The dragon-fly can fly backwards as well as forwards, and with lightning-like speed. [See Fig. 6, Appendix.].

4. *Membrane-winged.*

The bee, like the dragon-fly, has four transparent wings; but the veins are much less numerous. The name is not a good one, because all wings are membranous; but there is no difficulty in distinguishing members of the group, because the hinder pair of wings are fastened to the front pair by little hooks along the edge. Bees, wasps, ants, and saw-flies are *membrane-winged.*

5. *Scale-winged.*

The butterflies and moths are distinguished by having their wings covered with beautiful scales, and hence are called *scale-winged.* When handled, the scales adhere to the fingers as dust; but under the microscope they are beautiful objects.

6. *Two-winged.*

The blue-bottle, daddy-long-legs, the gnats, the common fly, and many other flies have two wings, hence the name.

II. Benefits derived from Insects.

Insects are small, and as an article of food for man of not much importance; but as diet for bats, birds, frogs, toads, moles, &c., they are of incalculable benefit.

The larvæ of beetles, and the caterpillars of butterflies and moths, are eaten with much relish in some parts of the world. Locusts have formed an article of diet in North Africa from time immemorial, and white ants furnish an abundant supply of food for the Hottentots of South Africa. Bees provide us with honey and wax, and silkworms with silk. The cochineal insect yields a fine scarlet dye, and to the gall-fly we are indebted for the chief ingredient in the manufacture of black ink. Some insects also act as scavengers, removing decaying animal matter which would otherwise taint the air; and they act as checks on themselves, one species preying on another, and thus preventing its too rapid increase.

III. Injuries caused by Insects.

Some insects cause us annoyance rather than injury, the common house-fly, for example; others, like the mosquito and gad-fly, are nothing less than tormentors; but some there are which in their vast numbers become veritable scourges. Swarms of locusts occasionally devastate whole countries, eating up every green thing. The cockchafer as a grub is a pest to the farmer, for it lives three or four years underground, and feeds voraciously during the summer on roots; and as a perfect insect is no less a scourge, sometimes appearing in such vast swarms as to destroy whole forests. The larvæ of the skip-jack beetle, known as wire-worms, feed on the roots of corn, and sometimes do immense injury. The wood-boring beetles destroy great

numbers of trees. Whole crops of turnips are often destroyed in a few days by the turnip-fly; and the hop-fly is equally destructive to the plant on which it feeds.

LESSON XLIX.

INSECTS. III.

(Metamorphosis.)

In summer time, the teacher will experience little difficulty in securing plenty of specimens of eggs, grubs, caterpillers, pupæ, and perfect insects with which to illustrate this lesson.

The life-history of an insect is a most interesting one. In most cases, but not all, before the animal becomes a perfect insect it passes through *three* stages: the *egg* stage, the *masked* or *larva* stage, and the *baby* or *pupa* stage.

I. The Egg Stage.

The eggs of insects are very small, but they have a yolk and a white portion like the bird's egg. [For information on eggs of insects see Lesson LXI.]

II. The Larva Stage.

After a certain time, varying in different insects, and also with the time of the year, the young larvæ eat their way out of the shells and set about what appears to be the business of their lives, *eating* and *sleeping*. They seem to be born to devour, and to be devoured.

It is in the larva stage of growth that insects do most damage to the farmer's crops. But eating so voraciously they quickly increase in size, and the skin is no longer able

to contain the body; so, hiding for a short time in a corner or under a leaf, the caterpillar or grub splits the skin down the back, and crawls out clothed in a bright new raiment. "It is not enough to say that they change their skins. The cases are so complete that they may be taken for entire caterpillars. The hairs, the leg cases, the nails with which the legs are provided, the hard solid parts which cover the head, the teeth, all these are found in the skin which the insect abandons." This change of skin takes place four or five times.

The following table, for the blackboard, shows the period of each stage, and the weight of leaves consumed by the caterpillars from one ounce of eggs—

Stage.	Days.	Weight of leaves consumed.
1st	5	6 lbs.
2nd	4	22 "
3rd	6	65 "
4th	7	200 "
5th	9	1,200 "
	31	1,493 lbs.

The larvæ of insects are commonly known as *maggots*, *grubs*, and *caterpillars*. Some have no limbs and no distinct head, these are *maggots;* those which have a distinct head and no legs (or only six legs) are *grubs;* and those which have a head and six legs, and, in addition, some fleshy feet on the back part of the body, are *caterpillars;* but there is no strict dividing line between them. The young of flies are chiefly *maggots*, those of beetles are *maggots* or *grubs*, those of moths and butterflies are *caterpillars*.

It is worthy of note that the larvæ of some insects, those of the gnat and dragon-fly, for example, pass their grub

stage in the water, while the perfect insect soars aloft in the air on light and gauzy wings.

III. The Pupa Stage.

The period of feasting being over, and the time for the last change of skin having arrived, the larvæ again seek retirement, and this time for a more lengthened period. Some are content to hang by a thread from a leaf or branch, others hide under leaves, or underground, or beneath the bark of trees; some gum together a case of leaves, others build a palace of mortar kneaded with fluid silk, and finely plastered within; while a few, like the silkworm, spin cocoons of "beautiful silk," in which they may undress and sleep, withdrawn from the vulgar gaze. In such retreats the shedding of the last skin takes place, with the result that no longer emerges the larva, but a new being wrapt in swaddling clothes. This is the *pupa* or *baby*, and is so called because the limbs are packed away under an outer skin, just as the legs and arms of a baby were formerly wrapped in swaddling clothes.

In this stage, *as a rule*, the pupa neither moves nor eats, but remains in a state of outward repose till the perfect insect is formed within. Then the skin splits for the last time, and the perfect full-grown insect emerges. In some cases, as in the earwigs, the pupa has its legs quite free, and is as active as the grub or the perfect insect.

IV. The perfect Insect.

On emerging from the pupa case the insect has weak and flaccid legs and wings; but in very quick time these acquire firmness and strength, and the insect flies abroad with the same ease and certainty as if it had spent a life-time in the practice.

One important point to be remembered about the perfect insect is that it never grows; as it comes from the pupa case,

so it remains. Some perfect insects live but a short time and never feed at all; and some, which were very voracious as caterpillars, simply sup the dainty nectar from the cups of flowers.

NOTE.—An interesting lesson to little children may be given on the silkworm, provided the teacher can keep a few of the caterpillars, and allow them to spin their cocoons.

LESSON L.

INSECTS. IV.

(Legs and feet.)

ILLUSTRATE with diagrams and specimens.

I. General Structure.

Question on the hardened covering of the body of the insect, and tell that the legs and feet are constructed in the same way. From the diagram show that each of the *six* legs consists of pieces jointed together—joints consisting of tough leathery skin. Legs jointed to chest by a piece called *coxa*, the joint acting very much as a ball-and-socket joint. Between the *coxa* and the *thigh* there is another piece; sometimes a ring-like joint, and sometimes a plate extending along the under surface of the thigh. The *thigh* is usually the largest and most powerful part of the limb. The *leg* follows, and the joint acts as a hinge-joint like our elbows. The *foot* is similarly jointed to the leg. It consists of a variable number of pieces following each other like joints, usually *five* in number, never more. The whole of the leg is generally covered with stiff hairs, and the last joint of the foot bears at its point a pair of movable claws.

II. Modifications.

The legs of insects, like those of the higher animals generally, are mainly used for walking or running, and for these purposes they undergo but slight changes of structure; but when special functions have to be performed the modifications are necessarily greater. We will take *three* illustrations of the latter—modifications for *swimming, burrowing,* and *jumping.*

1. *Swimming.*

The best example of leg modification for swimming is the common water-boatman. This insect can fly well, and also walk; but passes most of its time in the water, and in the water finds its food. Hence it needs to be provided with some apparatus for swimming. This is furnished by the last pair of legs; they grow to a great length, and are fringed with stiff hairs forming oars of a very perfect kind. When engaged in swimming, it turns itself on its back, and propels its boat-like body by the using of these legs as oars, just as a boatman uses a pair of sculls.

And the resemblance does not cease here. All good oarsmen "feather" their oars, viz. turn the blade edgewise on leaving the water so as to cut through the air with the least amount of resistance (Illustrate.) Now the water-boatman does not lift its oars from the water, and therefore has the more need to "feather" its oars because the resistance of the water is much greater than that of air. The blade-bristles spread themselves out during the stroke, and fall together during the return. (Compare the action of the foot of a duck in swimming.)

2. *Burrowing.*

We take the mole-cricket as an example of burrowing insects. It is so called from its resemblance to the mole in its habits. Like the mole, the mole-cricket forms galleries underground, and constructs a chamber in which to reside; and like the mole too, it feeds on insects and worms. In the

water-boatman the hind pair of legs forms a pair of oars, in the mole-cricket the fore pair forms toothed spades for digging. These legs are short, and stout, and very strong, and the feet which form the real digging organs are flattened and turned outwards like the fore-feet of the mole. Notwithstanding that these insects spend the greater part of their time underground, they occasionally take flights abroad in the evening.

3. *Jumping.*

The well-known grasshopper is a jumping insect. Compare long legs, and strong muscular thighs, with those of kangaroo, frog, and other jumping animals.

LESSON LI.

INSECT AND SPIDER (a comparison).

LOWER STANDARDS.

ILLUSTRATE by diagrams and pictures.

Insects.	Spiders.
(*a*) *Body* consists of three parts.	(*a*) *Body* consists of two parts. (Head and thorax form one part.)
(*b*) *Segments,* distinguishable.	(*b*) *Segments* not distinguishable.
(*c*) *Skin* hard, except between the segments. Cast only in the larva stage.	(*c*) *Skin* soft and leathery. Cast at irregular intervals during life.
(*d*) *Legs.* Three pairs, each made up of *five* pieces; claws at end.	(*d*) *Legs.* Four pairs, each made up of *seven* pieces; (thigh and leg each *two* pieces); claws at end.

Insects	Spiders.
(*e*) *Wings.* Two pairs, of which one pair, or both pairs may be wanting.	(*e*) *Wings* never present.
(*f*) *Feelers.* One pair: vary very much in form. Probably used for feeling.	(*f*) *Feelers*, changed into a formidable pair of jaws. Each consists of two pieces, of which the outer is claw-like and capable of being folded back into a groove of the other. Canal throughout connecting with poison gland.
(*g*) *Spinning* apparatus, found in some insects, especially caterpillars. Thread passed out through mouth, and hole in lip. Spin cocoons in which to live, or pass from larvæ to pupa state, or thence to the perfect insect.	(*g*) *Spinning* apparatus possessed by all spiders. Spinnerets on under surface of body near the end. Spins cocoons as egg-cases, also webs as traps, or habitations.
(*h*) *Eyes*, compound, a pair, each containing a large number of simple eyes.	(*h*) *Eyes* simple, and varying in number from *one* to *six* pairs.
(*j*) *Breathing* apparatus consists of tubes running throughout the body.	(*j*) *Breathing* apparatus, little sacs opening on the under surface of the body towards the front. A few have air-tubes also.

LESSON LII.

LEGS AND FEET. I. (Mammals.)

Any leg or feet-bones will be useful, especially those showing the joints. Diagrams of limb-bones.

I. Introduction.

Explain the word mammal, if not already explained; almost all mammals have *four limbs* [The hind limbs of the whale are not developed.] In man the *fore-limbs* are arms and hands; and in monkeys, all the legs have hands; and in bats, the fore-limbs become wings: but in the great majority of cases the limbs consist of *legs* and *feet.* In this lesson we consider the limbs of man, because they are always taken as the model with which to compare others.

II. The Parts of the Limbs.

The children to name the parts, and the motions of the joints; and the teacher to call attention to the *general correspondence* in the parts of the two pairs of limbs, and their motions.

Thus the *arm* and *thigh*, the *fore-arm* and *leg*, the *wrist* and *ankle*, the *hand* and *foot*, the *fingers* and *toes*, all correspond generally in situation and form. Then as to motions, the *arm* and *thigh* can be moved in almost any direction from the shoulder and hip, although the motion of the arm is more extended; the *elbow* and *knee* allow of but one movement, viz. backwards and forwards; the *wrist* and *ankle* move pretty much like the knee and elbow, but have some power of motion in other directions; the *fingers* and *toes* have the same number of joints, with power of motion in the same direction, except that the thumb has other motions. Both fingers and toes have nails.

III. The Bones.

Draw attention to the diagrams of the bones of the arms and legs. Give the bones their common names and arrange on the blackboard.

Arm and Hand.	*No. of Bones.*	*Leg and Foot.*	*No. of Bones.*
Arm	1	Thigh	1
Fore-arm	2	Leg	2
Wrist	8	Ankle	7
Hand	5	Foot	5
Four fingers	12	Four toes	12
Thumb	2	Great toe	2
		Knee-pan	1
	30		30

IV. Joints.

Elicit from the children that without bones we could not stand, and without joints we could not move. Then call attention to, and illustrate more fully, the varied movements permitted by the joints; and on this classify into ball-and-socket joints, and hinge-joints. Show next how that the bones would slip out of joint were they not tied together in some way. Secured by strong white cords, or *ligaments*, passing from the cup to the ball, or from bone to bone.

V. The Muscles, Nerves, Blood-vessels, and Skin.

Explain very generally the uses of these. The muscles are organs of movement. They are stretched from bone to bone, and by their contraction move the bone on the joint. Illustrate with the biceps muscle, which raises the arm on the elbow-joint. Within the muscles are nerves and blood-vessels; the latter bring nutriment and take away waste; the former are organs of feeling, and they further serve to carry messages from the brain to the muscles, directing and guiding their movements. The skin is a protecting covering over all.

LESSON LIII.

LEGS AND FEET. II. (Mammals.)

I. Introduction.

We have in this lesson to consider the chief purposes (*functions*) which the legs and feet are called upon to serve in the animals which suckle their young, and the modifications consequent thereon. We use different kinds of tools for different kinds of work, and so it is with animals. The cow is not fitted for climbing trees, nor the monkey for running a race on "all fours." On the other hand a monkey in a tree, a seal in the water, and a bat in the air, are as active and graceful in their movements as they are awkward and ungainly on the land. Thus while the general plan of structure, as described in the last lesson, is ever retained, the details are so modified as to form tools fitted for very diverse purposes.

The great function of the limbs is of course locomotion; but then the locomotion is very variable in kind. One animal has to make its way among the branches of trees, another on the ground, another in the air, a fourth through the water, a fifth through the soil, and so on. And for each purpose the same tools are used, though so modified as outwardly to resemble new tools altogether. By a few questions the teacher will be able to elicit that the chief modes of progression, in addition to the more ordinary *walking* and *running*, are *climbing*, *flying*, *swimming*, *burrowing*, and *jumping*.

II. Uses of the Legs and Feet in Locomotion and the consequent Modifications in Structure.

1. *Walking and running.*

In ordinary walking and running some animals plant the whole sole of the foot on the ground, while others walk and

run on their toes. In the latter case the foot seems to form another leg-joint. Look at the legs of the cat, for example. In the fore-leg the elbow is seen not far from the body, and the wrist appears as another joint lower down. In the hind leg the knee is seen to correspond with the elbow, except that of course it points forwards, while the heels show lower down as a reversed knee. What particular purpose does this special organization serve? A cat-like tread is a common expression. It refers to the silent, stealthy footstep of the cat, brought about firstly by walking on the toes, and secondly by the beautiful, soft, leathery pads beneath the toes. Walking on the toes gives a lightness and springiness to the movement not otherwise obtained. Most of the land *carnivora* walk on their toes. Horses, cows, sheep, deer, camels, elephants, and many of the smaller common animals walk on some modification or other of the toes.

2. *Climbing.*

A foot like ours is of but little use for climbing, and so in monkeys the feet are shaped like hands, with fingers and thumbs on all, and the monkey is said to be *four-handed.* Some monkeys travel more by making long jumps from branch to branch, catching by the hands, than by climbing with "all fours." Now if you watch a boy suspend himself from a bar, you will note that he always keeps his thumbs side by side with his fingers, and not opposite to them, as he does in holding a walking-stick; and so in the monkeys referred to, the thumb is placed side by side with the fingers and cannot be opposed to them.

Other mammals beside monkeys climb trees—the squirrels, rats, and some of the cat tribe, for instance. The body of the squirrel is not sufficiently bulky to require very strong hands for support, nor are its paws sufficiently large to grasp branches of any size, so the legs are short, and the nails are changed to long, curved, and sharp claws, which secure a strong foothold even upon the upright tree-trunk. A curious

modification of the hind-leg of a rat enables it to descend perpendicular walls with great ease. The foot is so articulated at the ankle, that it can be turned half-way round and the claws pointed backwards. The animal can thus hang from its hind-claws head downward. The sharp, strong claws, and powerful bones and muscles, enable some members of the cat tribe to climb the trunks of trees, and secure themselves among the branches.

3. *Flying.*

The only mammals which fly are the bats. Refer to picture of skeleton to show that the bones of the wing correspond with the bones of our arms and hands; but that the wrist and finger-bones are developed to an enormous extent. Then from a picture of a bat on the wing show how a thin membranous skin is stretched over and between the bones, the whole forming a very efficient flying apparatus.

LESSON LIV.

LEGS AND FEET. III. (Mammals.)

I. Special Uses (*continued*).

4. *Swimming.*

Some of the mammals which live in or frequent the water prey on fishes. Now fishes propel themselves by means of the tail-portion of their bodies with lightning-like velocity through the water, and the mammals must have their limbs so modified for swimming purposes as to render their possessors equal or superior to the fishes in quickness of movement. Whales, dolphins, and porpoises have their bodies shaped like that of the fish, the fore limbs are merely fins for balancing, or for holding their young during suckling. The

hinder limbs are absent altogether, and a broad tail-fin placed at right angles to the body of the fish is the organ of locomotion. [Illustrate this, and compare with tail-fin of fish.] Seals too have their bodies tapering like the whale, but unlike the whale they possess *four* limbs. The toes of the feet are *webbed* like those of the duck, and form very efficient oars. In one large family of seals the hind leg bones are turned backwards in a line with the back, and closely bound to the tail by a strong membrane. The broad webbed feet, flippers as they are called, placed close together form a tail of great power in swimming. The bones of the fore-legs are very much shortened and thickened, and little more than the webbed toes are visible outside the body. On land, seals hobble about in a very ungainly fashion ; but in the water they are all grace and power. The hind feet of the otter, the polar bear, and the beaver, are flat and expanded, and the toes are webbed like those of the seal. They are used as paddles.

5. *Burrowing.*

The fore-feet of the mole afford the most striking example of digging organs. The bones of the arm are shortened and strengthened. Those of the hand are enormously large in comparison with the size of the body, and are furnished with strong, sharply curved, and flattened claws. The paw itself is set on the fore-arm rather obliquely for greater freedom of movement in burrowing, and the whole limb is furnished with powerful muscles.

6. *Jumping.*

The jumping mode of locomotion is best illustrated by the kangaroo, though many other animals, notably the jerboas and the hares, proceed in a similar manner by a series of bounds on the hind-limb.

In the mole the fore-limbs are much enlarged. In the kangaroo it is the hind limbs which undergo an extra enlargement. The fore-limbs are small and feeble, and

the hind limbs alone are used in progression. The animal uses these with such effect that it covers more than a dozen feet at a single bound, and continues these long jumps for a considerable length of time without appearing to tire. One toe of each hind foot is provided with a specially large strong nail, making a formidable weapon of offence and defence. In the hare again the hind-limbs are very much longer in proportion than the fore-legs, and the animal "shoots along over the ground by a series of long leaps, with great swiftness." In the jerboas the development of the hinder limbs is seen in perhaps the greatest degree; some of them can spring from twenty to thirty feet at a bound.

LESSON LV.

LEGS AND FEET OF BIRDS. I.

DIAGRAM of leg bones, pictures of legs of birds.

I. The Skeleton.

Show from the illustration that the bones of the leg of a bird are arranged on the same plan as those of mammals, but in a considerably modified form. We find a *thigh* bone and *two leg* bones always present, though the smaller of the two latter is often but imperfectly developed. Then, in place of the ankle and foot bones, there is a single long bone called the *tarsus*. To the tarsus, which is commonly looked upon as the leg-bone, the toes are jointed. The *toes* vary in number and arrangement, and in the number of joints in each. Generally there are *four*, of which *three* are in *front* and *one behind*. [The ordinary position of the toes may be shown from the leg of a barn-door fowl.]

II. How Birds Perch.

The special arrangement, by which most birds can sit and sleep on a branch or twig, is the most interesting and striking peculiarity in the structure of the bird's leg. All children will have seen how a canary *clasps* its perch with its toes, and will know in what position the bird sleeps. A boy can balance himself sitting on a branch, and he may "hold on" to secure his seat; but should he fall asleep he would be certain to get a fall of another kind. But when a bird sits down on a branch to feed, to rest, or to sleep, it cannot fall off if it would. The very act of sitting down makes the toes clasp the branch, whether the bird wills it or not. The arrangement is this: a flat ribbon-like cord passes from a large muscle of the thigh over the knee joint, and then winds over to the back of the leg, being kept in its place by a small muscular ring. It then passes down behind the leg bone, and over the back part of the joint of the leg bone with the tarsus, where it passes through a second muscular ring. It continues along the back of the tarsus to the junction of the toes, and then divides into cords which pass along under the toes.

By this arrangement, when the joints are bent as they are when the bird sits down, or when it raises its foot in walking, the cord is stretched, or pulled, and the toes are made to grasp without any effort on the part of the bird. The teacher may show this from the illustration, but a far more instructive illustration will be to show the actual working of the cords in the leg itself. Take a fowl's leg. Cut through the skin at the joint between the tarsus and leg. and dislocate the joint with the point of the knife; a smart pull will break the cord at its junction with the muscle in the thigh, and it will be drawn out as a soft, thick, but very strong white ribbon. Pull this cord, and the toes will close as if grasping.

Advantage may be taken of the specimen to show the scaly covering of the leg.

III. Special Uses and Modifications in Structure.

We have now to consider the different duties which the legs have to perform, and the consequent changes in structure. All are used more or less in walking, hopping, or running; very many are used as supports during rest and sleep, and not a few are used as hands to hold the food while the beak cuts or tears it in pieces. [Refer to the blackbird with an earth-worm, canary with chickweed, parrot with nut, &c.]

At the same time the special structure of the legs and feet of birds for special duties are sufficiently marked to enable us to arrange the birds in groups accordingly. Thus we have *Seizers* like the eagle, *Perchers* like the robin, *Climbers* like the parrot, *Scratchers* like the fowl, *Runners* like the ostrich, *Waders* like the heron, and *Swimmers* like the duck.

LESSON LVI.

LEGS AND FEET OF BIRDS. II.

To be illustrated by pictures and diagrams on the blackboard.

Recapitulate as to classes of birds, and write names on blackboard with one or two examples in each class.

I. Seizers. "*Birds of Prey.*"

In this group the legs are strong, and the toes are furnished with strong, curved and sharply pointed claws specially adapted for the capture of living prey of considerable size. The vultures, eagles, hawks, and owls are all "birds of prey." The members of this group have four toes—three before and one behind; but the owls can place the outer toe of the three either in front or behind.

II. Perchers.

This group includes the vast majority of the small birds which live in this country. They are also called *passeres* [*passer*, a sparrow]. These birds for the most part spend the greater portion of their lives among the branches of trees and hedges, on which they perch, and hop from twig to twig. Their feet are specially constructed for this purpose. The toes are usually three in front and one behind, and the claws are sharp, but long and slender, and of sufficient strength to secure the bird firmly to its perch.

III. Climbers.

All the birds in this group have *two toes before* and *two behind*. This enables them to cling with great tenacity to the branches of trees, or to climb up the perpendicular tree trunk. Parrots and woodpeckers are the chief examples of the group. Parrots climb rather by *clasping* small branches. Woodpeckers run over the bark of the tree-trunk, and larger branches, in every direction by inserting their strong, sharp claws into any irregularities of the surface.

IV. Scratchers.

Chiefly barn-door fowls and game birds. Show the leg of the fowl again in illustration, and point out that the legs of scratchers are strong, the toes rather short and thick, and the claws stout and strong and fit for scratching over the surface of the ground in search of food.

V. Runners.

These birds depend entirely on their legs for locomotion, hence they are long, stout, and strong. They never perch, and few toes are required. In the ostrich they are reduced to *two*, and in the emu to *three*, and they are all pointed forwards. [The teacher may here refer to the speed of the ostrich, to an ostrich hunt, and to its manner of defending itself by kicking forwards.]

VI. Waders, or Stilt-Walkers.

These birds, of which the heron and crane are familiar examples, *wade* into the water after the food on which they feed, hence their legs are of unusual length. The length of leg has won them the title of stilt-walkers.

VII. Swimmers.

This group includes geese, ducks, and sea-birds generally. The feet are specially constructed for swimming. [Show duck's foot.] The legs are short and strong and placed far back on the body, and the toes are united by a stout membrane—the web.

LESSON LVII.

FLOUR.

For illustration, provide specimens of flour from any or all of the following:—Wheat, barley, oats, rye, rice, and maize.

I. Constituents of Flour.

Take a small quantity of either of the specimens, add water and knead into dough. Tie the dough in a muslin bag, and well work it with the fingers in a vessel of cold water. The water becomes milky, and if allowed to stand for some time a white powder falls to the bottom. This is *starch*. There remains in the bag a thick glutinous substance; this is *gluten*. It is to the starch and the gluten, but especially to the latter, that the nutritive property of flour is due. Besides starch and gluten, flour always contains water, woody matter, a little fat and sugar, and a small quantity of mineral matter.

The following table shows the composition of one pound of each of the various kinds of flour.

COMPOSITION OF ONE POUND OF VARIOUS KINDS OF VEGETABLE FOOD.*

	Water.		Ashes.		Heat-givers.						Flesh-formers						Accessories.			
					Starch.		Fat.		Sugar.		Gluten.		Casein.		Albumen.		Cellulose.		Gum.	
	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.	oz.	grs.
1 lb. of wheat . . .	2	106	0	112	9	242	0	54	0	385	2	21	—		0	126	--	119	0	119
,, barley . . .	2	106	0	293	7	297	0	20	0	265	2	22	—		—		2	50	0	258
,, oats	2	78	0	210	6	153	0	397	0	378	2	316	—		—		2	6	0	210
,, rice	2	70	0	34	11	380	0	48	0	27	1	1[illegible]	—		—		0	230	0	68
,, maize . . .	2	105	0	70	9	262	1	101	0	21	1	402	—		—		0	350	0	21
,, beans . . .	2.	161	0	245	5	333	0	140	0	140	—		3	368	—		1	206	1	156
,, peas	2	112	0	175	5	403	0	140	0	140	—		3	324	—		1	263	1	193
,, potatoes . .	12	0	0	64	2	219	0	15	0	223	0	100	—		—		0	224	0	30

* From Dr. Lankester's "Lectures on Food."

II. Flour as Food.

The chief use of starch as a food is its *heat-giving* property, and the chief use of gluten is as a *flesh-former*. Call the attention of the children to the table, and it will be seen that some of the other cereals are quite as valuable for their nutritive properties as wheat. For instance, there is quite as much, if not more, nutritive matter in oats. Barley again would appear to be as valuable as oats, and maize has in addition a large quantity of oily matter, which is not found in any quantity in any other cereal. Why then do people all the world over always prefer wheaten bread to any other, although the price is higher? Doubtless it is that wheaten flour alone will make good fermented or "light" bread. Bread made from the flour of oats, barley, or maize is always "heavy." A mixture of wheaten and maize flour will, however, ferment and make fairly good bread.

Barley-bread is not very palatable. It is coarse and dry, and apt to become sour.

Rye-bread is largely used by the poorer classes in Russia. It is coarse and heavy, dark in colour, and unpalatable.

Oat-flour, or *oat-meal*, is used for making cakes, and the Scotch people use large quantities of this nutritious meal in the form of cakes, and in porridge.

Rice-flour, or *ground-rice*, is used mainly for puddings and cakes.

Maize-flour is used for mixing with wheaten-flour to make bread; but its chief use is for porridge, puddings, and cakes.

LESSON LVIII.

THE FROG. I.

THE teacher should if possible secure a specimen. It may be kept on the table in a small wire cage, with a sod of grass for the floor. A picture of skeleton, and, failing the living specimen, a picture of the animal itself will be necessary.

I. General Appearance.

Were it not for its association with the toad, it is more than probable that children would be much better acquainted with the pretty, harmless frog than they usually are; but as it is, the teacher will be able to elicit some facts with regard to general appearance, and mode of progression.

The body is broad, and short, and squat, and without a tail. The head is broad, triangular in shape, and very large in proportion to the size of the body. The *hind* limbs and feet are very long, and the toes—*five* in number—are webbed. The *four* toes of the fore-limbs resemble fingers, and are sometimes used as such. The skin, which is of a greenish brown, yellow, or reddish colour, is naked and covered with a slimy fluid. The eyes are large and prominent. Held in the hand the animal feels clammy, and cold.

II. Locomotion.

The children will readily associate the jumping mode of progression on land with the long hind legs; and the teacher should compare with other animals, such as the rabbit, which move in a somewhat similar fashion.

The webbed feet will suggest the swimming powers of the animal, and indicate the fact that it is its habit to live in the water as well as on the land. [If the teacher has a living specimen, the frog itself will demonstrate in a vessel of water how it swims.]

III. Breathing.

The teacher will call attention to the skeleton of the frog, showing that it has *no ribs*. Now in breathing we make use of our ribs to enlarge the cavity of the chest, and so admit the air through the nostrils or mouth into the lungs. [Show how this is done.] The frog, having no ribs, must get the air into its lungs in some other way, and this way is a very curious one. The frog simply swallows the air, as we swallow our food. Try and swallow with the mouth open. You cannot; neither can the frog; and to suffocate a frog therefore it is only necessary to keep its mouth open.

The frog closes the lips, and expands the cavity of the mouth, the air then enters through the nostrils. The mouth being full, the nostrils close like valves, and the upper portion of the tube leading to the stomach closes also. Lastly the walls of the mouth contract, and the air is squeezed into the lungs. Watch the frog, it seems to be constantly swallowing; and so it is, it is swallowing air. But clearly this method of breathing does not take in a very large supply of air, and although it is probable that a considerable additional quantity is admitted through the moist skin, sufficient is not taken to make the blood as warm as ours.

A boy in running breathes faster, takes in more air, and gets warmer. Birds breathe very fast, and have very warm bodies. Frogs breathe slowly and take in less air; their blood is colder than ours. They are called cold-blooded animals.

IV. Feeding.

The food of the frog consists of living insects, snails, and worms; and, as it swallows its prey whole, it needs no teeth with which to grind. It would be difficult, however, for a frog to hold a wriggling worm with the lips only, and so it is provided with a row of small teeth round the upper jaw. It is a curious sight to watch a frog in the act of swallowing

a worm, pushing it into its mouth with the fingers of the forepaws, the worm all the while twisting and turning in its efforts to escape.

Insects, however, such as flies, are the favourite food of the frog. And how is it to capture prey swifter by far in motion than itself? It is provided with a special organ in its curious tongue. [See page 165.] This fleshy organ has its root or base in front instead of at the back of the floor of the mouth like ours, and when at rest the tip of the tongue points backwards towards the throat. This arrangement permits the owner to protrude almost the whole of the tongue so that the tip extends far beyond the lips. There is also another curious provision; the tip is covered with a thick sticky matter resembling glue. How does the frog use this curious "fly-catcher"? Watch it; a fly is within striking distance. You see a flash of something red from the frog's mouth, and the fly has disappeared. The action of the tongue, as it is shot out and withdrawn with the fly on its tip, is so rapid that it can hardly be followed. [The teacher should compare the action of the frog's tongue with that of the chameleon, and ant-bear.]

V. Haunts.

Frogs cannot breathe in the water, except perhaps a little through the porous skin, neither is the fleshy tongue suitable for taking prey in the water. Hence frogs must spend the greater portion of their time on the land. Yet water is necessary to their existence. They require plenty of moisture to keep the skin in a moist state. Kept in a dry place the skin of the frog shrinks and dries, and becomes like stiff parchment, and the animal soon dies. Hence we usually find frogs near ponds and ditches, and for the same reason frogs appear to be more plentiful after storms, because the moisture tempts them from their hiding places.

There is another reason, too, why frogs frequent the

neighbourhood of water. At the bottom of the water they lay their eggs, and during the winter, when insects and slugs are not to be found, they sleep securely beneath the mud until the warm weather comes again.

VI. Uses.

Frogs are useful in gardens because they destroy the insects and slugs which feed on the vegetables and flowers. In some countries frogs are eaten, and are considered a dainty diet. In their turn, too, they serve as food for other animals, such as snakes, hedgehogs, &c.

LESSON LIX.

THE FROG. II. (Life-history.)

LIVING specimens of tadpoles in their various stages of development will make this a very interesting lesson. They are easily kept some time in a warm corner. Failing the living specimens, pictures must be provided.

I. From Egg to Tadpole.

Few animals can boast so interesting a life-history as the frog. In the early spring, children in the country must have noticed in the ditches and ponds floating masses of jelly-like beads glued together. These are the eggs of the frog. In looking at the *spawn*, as these egg-masses are called, we do not see the eggs at all, or at most, only as tiny specks within the jelly-beads. The eggs, tiny as pins' heads, and covered with a glairy substance, are deposited at the bottom of the water. The slimy envelope absorbs water, and the mass rises to the surface. The bead enclosing each head is now about the size of a pea. Toads, as well as frogs, lay their eggs in the water, but the toad arranges her eggs in double strings instead of masses.

Unlike birds, frogs take no further trouble about their eggs after being laid. In due time, however, they are hatched, and out of each there comes, not a frog, but a creature quite unlike a frog in every particular—a tadpole.

The name, which very well describes the animal, is a contraction of *tailed-poll;* and *poll* being another name for *head,* it means *tailed-head.* And indeed the tadpole looks nothing but a head, with a flat tail attached thereto.

II. From Tadpole to Frog.

Now we must examine these tiny *heads* with *tails* as they dart and glide about in the water. In the first place we shall see on each side of the head little pink tufts. These are gills. They act like the gills of a fish, and enable the tadpole to breathe, as it were, through the water. [The teacher may show the gills of some common fish, as the herring.] It will be interesting to look at the tadpole of larger growth, to see what changes are brought about as they grow. But first the teacher will tell the children that rather below than in front of the head there is a mouth, and that this little mouth is surrounded by thin horny plates sufficiently strong to enable the owner to nibble off the soft vegetables on which it feeds. [Compare this kind of feeding with that of the frog.]

If living specimens are provided the children will be able to note the more evident changes. As the body increases in size the gills are enclosed in a little cavity ; but they soon diminish in size, and the tail shortens. It is possible now on close inspection to find a pair of little knob-like projections just where the tail joins the body. These are the first signs of the legs. The legs are formed before the skin is broken. This tadpole has only one pair of legs, but an older tadpole shows another pair of knobs in front of the pair of legs. These will later on become the front pair of legs.

And so the growth and the changes go on for many

weeks; the gills continue to diminish, and the tail to shorten, until none of either is left. Meantime the body grows full and broad, the mouth gets round to the front, and broadens out, and the horny plates fall off. In addition to all this, no less interesting and important changes have been going on inside the body. In the place of gills *lungs* have been formed, so that the animal which before could breathe only in the water, can now breathe only in the air; and the *heart*, which in the tadpole had only *two* chambers like a fish, has now *three*, like other reptiles. In fact, externally and internally a complete *metamorphosis* has taken place. The tadpole, formed to live, and move, and have its being in the water, has become changed into a frog, fitted in every respect for its new life on the land.

After the change is complete it takes several years before the frog is full grown.

There is one other curious fact to record in the life-history of the frog. Like the snake, it periodically sheds its coat; but unlike the snake, the frog works the shed skin, with the help of its fingers, into a little ball, and, pushing it into its mouth, swallows it.

LESSON LX.

EGGS. I.

EGGS of birds, eggs of fishes, and those of frogs and toads, may possibly be available.

Introduction.

The teacher should introduce this lesson by asking questions on the classification of animals into vertebrata and invertebrata, the former into mammals, birds, reptiles, and

fishes, and the latter into *soft-bodied* and *jointed animals*, besides other kinds.

All the *birds*, most of the *reptiles* and *fishes*, and all the *soft-bodied* and *jointed* animals, lay eggs. These eggs are of all sizes, from the huge egg of the ostrich to the dust-like eggs of the oyster; and they are of many shapes, and various colours. Some have a hard shelly covering, like that of birds' eggs; other coverings are leathery in texture, and many look and feel like beads of soft jelly. In this and the following lesson we propose to glance at a few of the most striking varieties.

I. Birds' Eggs.

Birds' eggs are well known to all children. They vary in size as the bird varies, and they have all pretty much the same shape (egg shape). The shells vary in colour in different kinds of birds, but are all of the same colour in the same kind of bird; and some of them are very beautiful. In internal structure they are all similar. All birds construct some kind of nests in which to place their eggs, if only a hole scooped in the sand; and all keep their eggs warm by the heat of their bodies until they are hatched.

II. Reptiles.

The eggs of the largest reptiles are similar in structure to those of birds. Those of land tortoises are enclosed in a hard brittle white shell. The shells of the eggs of marine tortoises, or turtles, are leathery, and feel like parchment to the touch. In some species they are spherical, while others are very much elongated. The eggs of reptiles are very much smaller, in comparison to the size of the animal, than the eggs of birds. Those of the crocodile, for instance, are not larger than the eggs of geese; but what is lost in size is more than made up in number. The female turtle lays from 150 to 200 eggs, and repeats the operation two or three

times a year. She deposits her eggs in regular order in a hole scooped in the sand on the sea-shore, and carefully covers them over.

A large number of snakes lay eggs. The common ringed snake lays from 16 to 20 in a warm, sheltered spot. Like the "spawn" of the frog and toad, they are stuck together by a thin glutinous substance. The dreaded cobra lays about the same number of eggs as the common snake. They are flattened, and about the size of pigeon's eggs. The shell is white, but tough and leathery.

The eggs of frogs, toads, and newts are extremely small. They have the appearance of small specks imbedded in thin jelly. The frog's are laid in clusters, and the toad's in double rows, like rows of beads; but the newt deposits her eggs in leaves, which she folds and sticks together for the purpose. The eggs of the frog and toad are black; those of the newt are a yellowish white.

Unlike birds, reptiles leave their eggs to hatch without any attempt at keeping them warm with their bodies.

III. Fish.

All the more common kinds of both sea and fresh-water fish lay eggs; and in some the egg masses become important articles of food. Most of the young sharks are born alive, but one kind at least—the dog-fish—lays about a dozen eggs. The female deposits them one or two at a time in a curious purse-like case, the walls of which are as tough as leather. These egg-purses are oblong in shape and flattened, and each corner is drawn out into a long tendril, like the tendril of the vine, or the pea. These tendrils or threads are elastic and very strong; and their purpose seems to be to attach the purse to sea-weed, or any other solid substance with which it comes in contact.

The chief feature to note of the eggs of fish in general is the enormous quantity to be found in the body of a single

fish. To illustrate this, the teacher may show the "roe" of a cod, or of a herring, or both. The eggs in the "hard roe" of a herring may be counted by thousands, those in the mackerel by tens of thousands, and in the cod, where the roe sometimes weighs more than the rest of the fish, by millions.

The roe of the cod is a useful item of food, and the eggs of the sturgeon form an important article of commerce, under the name of *caviare*. Fishing for the sturgeon in the rivers of Russia, especially the Volga, gives employment to many thousands of persons.

Fishes usually deposit their eggs in masses stuck together, in shallow water, where they fall to the bottom; but there is at least one fish common in the streams of our own country, which constructs a kind of nest. This is the pretty little stickle-back. The nest is made, and the eggs taken care of by the male, and not by the female; and several females lay their eggs in one nest. The eggs are very much smaller than those of the herring.

LESSON LXI.

EGGS. II.

IF this lesson is given in the summer it will not be difficult to collect some eggs of insects and spiders. Eggs of some crustacean may also be obtained.

Introduction.

By a short series of questions such as:—Why does the blackbird build her nest in a thick bush? Why does the eagle build on rocky cliffs? Why does the turtle bury her eggs in the sand? Why do many fishes ascend rivers to spawn? and so on, the teacher may lead the children

to see that a *wonderful instinct* impels all creatures to place their eggs in situations suitable and convenient for concealment, or protection, or warmth, or hatching, or for easy access of food for the young.

I. Insects.

In the case of insects this instinct is manifested in the very highest degree. Almost all insects lay eggs; but the animal whi.h comes from the egg usually is not at all like the parent. It is a grub or caterpillar, whose hunger can be satisfied only with an abundance of some special kind of food, quite different to that on which the parent feeds. Now except in a few cases, such as the ant, the bee, and wasp, the insect is not able to provide the food itself, it could not if it would. How could the common white butterfly, for instance, supply a score or two of hungry caterpillars, each of which is as large as itself, with sufficient cabbage leaves? or how could the sleepy silkworm moth provide a proper supply of mulberry leaves for its numerous progeny? Besides, in many instances, the parent insect dies before the young are hatched.

If the food cannot be taken to the grub, the grub must be carried to the food; or, which is the same thing, the eggs must be so placed that when the grub comes out, it will find its proper food close at hand. There are many thousands of different species of insects, and the young of each needs a different kind of food; and it is in the selection of the particular kind of food necessary for its future young, on which the insect itself does not and cannot feed, that the wonderful instinct comes into play. The question, "Where do insects deposit their eggs?" is easier to ask than to answer. We may almost say everywhere. In all parts of plants, roots, stems, pith, buds, leaves, flowers, fruit, nuts, seeds; in all sorts of decaying vegetable substan es; in hard wood and rotten bark, in dried bark and rotten wood: in skins

bones, furs, and leather; in meats fresh, salted, or putrid; in the interior of other insects, larvæ, and spiders; on other animals; in the earth, and even in manure. In every case they are so placed as to insure the safety and comfort of the future young.

The eggs of insects are objects of much interest; many of them are very pretty. The largest are but small, and many of them are microscopic, and some are so transparent that under the microscope the little grubs can be seen inside. Like birds' eggs, they are of many colours, but mostly white; unlike birds' eggs, they are of many shapes. The coverings of some are hard and smooth, many are ribbed and fluted, and marked with a variety of pretty patterns. Some look like beautiful seed-pearls, some resemble miniature rice-grains. Some insects deposit their eggs singly, others in bead-like rows; some like groups of nine-pins, others in masses and clusters glued together; while others are fixed round stalks of trees or bushes. Some insects have to deposit their eggs within other bodies—in the ground, in the bodies of other animals, and some provision must be made for boring the necessary holes, and putting in the eggs; and very perfect are the tools with which they are provided.

The cuckoo-flies, for instance, deposit their eggs in the bodies of other insects, or grubs. They are provided with what looks like a long tail, but which is really a *bradawl*, as fine or finer than a horsehair; not a solid bradawl, however, but one composed of three pieces, closely adherent when the hole is made, but opening to form a channel along which the egg is made to pass. Other insects have *egg-depositors* which resemble *augers;* others possess veritable *saws*, and so on.

II. Spiders.

Spiders spin pretty white silken cocoons in which to place their eggs. These cocoons, containing perhaps from 50 to

150 eggs, the female spider either carries about with her, or deposits in some safe hiding place. They may be fixed to leaves, stones, or other objects.

III. Crustacea.

Lobsters, crabs, prawns, and shrimps always carry their eggs in masses under the body. They are held together by a glutinous substance, and kept in place by the legs. Children will have seen them in the shrimp, and this will serve as an illustration for the others.

LESSON LXII.

SNAILS. I.

PROVIDE as many univalve shells as possible, and a few living specimens.

I. Shells.

Snails abound in all parts of the world, myriads in number, and in variety almost endless, and nearly all carry *shells*. Shells are the snails' houses, into which they can retreat when danger threatens, or to take needful rest.

We may arrange all snails roughly into two great classes: those which live in the sea, and breathe by means of gills, and those which live on land or in fresh water and breathe the air as we do. We will call them *sea-snails* and *land-snails*, always remembering that the latter include the pond and river-snails. The shells of all are *univalve*, that is, they are formed of one piece. [The teacher should compare the shell of a limpet, or a periwinkle, with that of the scallop and oyster. The latter possess *two valves* joined by a hinge, and are called *bi-valve*.] Some of the shells of snails, especially those found on the shores of warm seas, are very large, more

than a foot in length, and some are very beautiful and very costly.

Nearly all these shells have a spiral, or coiled-up form, like the common periwinkle; and, of course, the body of the snail when in the shell must be coiled up likewise. (Make a longitudinal section—by sawing—of a whelk-shell, to show the coils in the shell. Compare the specimens, to show that they are all coiled in the same direction, viz., from *left to right*. A few shells are coiled the other way, but these are the exceptions.)

II. Structure.

Direct attention to the *soft* bodies of the specimens. There is no internal skeleton of any kind. Then to the fact that the body is covered with a *thick skin*; this is called the *mantle*. The shell is secreted by this mantle; and it is the mantle which pours out the unpleasant slime of the garden-snail and slug.

On the under side of the body a fold of the mantle forms a broad foot, by means of which the animal *creeps* along with a gliding motion. (The word snail means a slow creeper.)

The head, which can be withdrawn within the mantle for protection, carries *feelers* or *tentacles*; in the sea-snails *one* pair, in the land-snails *two* pairs. These too can be withdrawn within the body of the animal. The longer pair of feelers in the land snails carries the eyes, and in the sea-snails the eyes are occasionally placed at the end of the feelers; but oftener they are seen at the base of the feelers, and on the outer side.

III. History.

With few exceptions snails lay eggs, either in water or in damp situations on the land. A few of them are conspicuous objects on the sandy shores of our own country after a

storm. For instance, the eggs of the whelk are found in clusters of membranous sacs (each sac containing five or six young), sufficiently light to be rolled along before a gentle breeze. They appear to be much too large to belong to an animal so small as the whelk. But then the eggs were quite small when laid; and, like frog's spawn, they have swollen to many times their former size. The eggs of the dog-winkle are more curious still; they are urn-shaped bodies, standing on a foot, and look very much like the wooden egg-cups sold in turners' shops. They are about a third of an inch in length, and placed separate from each other.

Usually the shells of snails' eggs are soft, but in a few of the larger kinds they are hard. The egg of the large Agate (land) snail is as large as that of the swallow, and the shell is quite as hard.

All snails are provided with a shell when first hatched, which in some kinds remains small and hidden in the mantle, or it may in later life disappear altogether. The common garden-slug is an example.

The food of snails is various. Many are carnivorous, and feed on "shell-fish;" a few are carrion feeders, but the great majority feed on plants. Most of them have horny jaws, and a curious ribbon tongue, covered with tiny teeth, pointing backwards towards the throat. This tongue forms an admirable tool for filing, boring, and rasping. (See next Lesson.)

Many of the snails, especially the Land-snails, pass the winter in a state resembling the *hibernation* of the larger animals.

Some of the Sea-snails have a peculiar growth on the foot, a kind of horny plate. When the animal retreats into its shell this forms a kind of door, which completely closes the opening. The periwinkle is a good example.

LESSON LXIII.

SNAILS. II.—WHELK AND PERIWINKLE.

LIVE specimens (in salt water) should if possible be placed before the class, in addition to the shells.

The whelk and periwinkle are the best-known examples of the Sea-snail.

I. The Shell.

The teacher should guide the children in a comparison of the whelk and periwinkle shells, both externally and in section. The sections show that the arrangement of the shell is such as would result from a long cone being twisted in a spiral manner round a fine rod as a centre, with the whorls touching each other. Some shells, such as the "Auger" and "Tower" shells, show the spiral arrangement much more clearly than the whelk or periwinkle. [A little ingenuity will enable the teacher to twist a cone of putty or clay to form a spiral, giving the outside form of the shell.]

Both whelk and periwinkle have the little horny plate (*operculum*) attached to the foot for closing the entrance, when the animal retreats into its dwelling-place.

There is one small but important difference in the structure of these shells. The margin of the opening of the whelk-shell has a *notch*, that of the periwinkle is entire. This difference, trivial as it may seem, publishes an important fact in the habits of the two snails. The carnivorous snails live in notched shells, the vegetable feeders in shells with unbroken mouths.

II. Structure of Body.

There is little to call for special mention in the structure

of the soft bodies of these snails which is different from other snails. They both possess the usual mantle, each has a pair of tentacles at the base of which are fixed the eyes, and they both breathe by means of little plume-like gills. There is, however, one important point of difference. The whelk has its mantle in front formed into a tube or siphon, through which the water passes into the gill-chamber. The reason for this is plain when we come to inquire into the habits of the animal. The whelk burrows for its prey, and the long siphon is thrust upwards above the surface of the sand or mud, so that the animal can breathe freely all the while the burrowing is going on. The periwinkle feeds on seaweed; and, not requiring the siphon, is not furnished with it.

III. The Tongue.

The most curious and extraordinary contrivance in connection with these and many other snails is the tongue. The whelk feeds on other "shell-fish," and as these other "shell-fish" close and bar their doors on the approach of their enemy, the whelk must be provided with some weapon or tool with which to breach the wall, and this weapon is the tongue. Examine the empty shells which can be picked up at high water-mark on any shore. In some at least you will be certain to find a tiny hole, smooth and perfect as though it had been drilled by a skilled workman. And so indeed it has; but the workman was the whelk or some one of its relatives, like the "Sting-winkle" or the "Dog-whelk," and its tool was its tongue.

This tongue consists of a long, narrow ribbon of gristle, covered on the upper surface with rows of microscopic teeth, all having their sharp points turned backwards. The teeth are made of flint, which is much harder than the limestone shells; and the whelks use them first as drilling-wimbles to bore holes, and then as rasps to drag out the soft and savoury food he finds within.

The tongue of the periwinkle is armed in a similar manner, but put to a very different purpose. Given a little sea-water and a few periwinkles it is easy to see these tooth-ribbons at work. When sea-water has been kept for a little while in a glass vessel a green substance appears on the glass. This is excellent food for the periwinkle, and to secure it the animal rasps it off with its long tongue, as a mower cuts grass with his scythe. The movement may be seen with the naked eye, but a pocket-lens makes the action very distinct.

[The common Pond-snail has a similar tongue, and the action may be seen in this case in fresh water.]

Whelks and periwinkles are used to a considerable extent as food. Whelks are caught usually by dredging, but may be caught in baskets baited with dead fish. Whelks are used by fishermen as "bait." Periwinkles are found just at the edge of low-water, adhering to the sea-weeds, on which they feed.

LESSON LXIV.

SNAILS. III.—GARDEN SNAIL, SLUG, AND POND SNAIL.

THE teacher may find it difficult to secure live specimens of the whelk and periwinkle; but there can be no difficulty during the summer months in finding plenty of specimens for this lesson.

I. The Shell.

The children will compare with each other and with the periwinkle. No very marked differences, except the absence of the operculum in the land-snails. The margin of the shell is entire, and the snails feed on vegetables, as indicated by this fact. The slug has no visible shell; but there is always a little flat plate enclosed in the mantle on the back.

II. Structure.

Bodies enclosed with mantle, except the slug, in which the mantle is merely a fleshy piece scarcely separate from the skin beneath. It occupies the fore-part of the back only, where it covers the lung-cavity. The foot in each case is very distinct, and rather long.

The head is short, and can be withdrawn, and hidden within the body. The slug and the garden snail have four cylindrical tentacles—*horns*, as they are commonly called. The upper pair are longer than the lower, and carry the eyes on their summits. When disturbed, the creatures slowly withdraw the tentacles by folding inwards from the tips, by a method similar to that in which we draw the "foot" of a sock within the "leg." The pond snail has but one pair of horns, and the eyes are placed at the base.

The mouth is armed with a broad cutting tooth in the upper part; but, in addition, each has the tooth-ribbon tongue, as described in the whelk, and periwinkle.

The lungs are small cavities enclosed by the mantle, the walls of which are covered with fine branching blood-vessels. Air is admitted through a small hole. In the slug the opening can be seen in the mantle on the right side near the margin. In the garden snail it opens under the mouth of the shell, and nearly in front.

III. Habits.

Land-snails are hibernating creatures. In hot, dry countries they sleep in the dry mud during the hot season, but come out after the first rain. In this country the garden snail retires to some hole or crevice in which to pass the winter. The snail buries itself in the soil, and the pond snail seeks the mud on the floor of the pond. The garden snail further protects itself in a curious way. With the slime secreted by the edge of the mantle it forms a thin sheet over the mouth of the shell. On drying this forms a

temporary door. Sometimes a second, and even a third, door is added within the outer one; but a small opening is always left to admit the air necessary for breathing purposes.

The garden snail and the slug are creatures of the night. They hide during the day-time under leaves or stones; but at night they come out and feed voraciously on young and tender plants, on fruits, mushrooms, &c. They also show themselves after rain.

Snails and slugs deposit their eggs below the surface of the ground, and are often brought into view when the soil is turned over in the process of digging. Slugs' eggs may often be found among the "crocks" at the bottom of flower-pots. They are a little larger than pins'-heads, and look like beads of semi-transparent jelly. They are stuck together by a substance which resembles white of egg. The pond snail fixes her eggs to the stalks and leaves of plants.

There are two other interesting facts in connection with the pond snails. It appears they are not always satisfied with the slow mode of progression on their fleshy feet; so they ascend to the surface of the water, turn over shell downwards, at the same time shaping the feet into shallow boats, and quietly glide along with the stream. The other fact is the formation of a cable—a fine, almost transparent thread—by which it fixes itself to some leaf or stalk, and, either rides at anchor, descends to the bottom, or returns again to the spot whence it started. The thread, which is not easily seen, seems to be formed of the same viscid secretion as that which surrounds and fixes the egg-masses.

LESSON LXV.

FIRST FORMS OF ANIMAL LIFE. I.—THE AMŒBA AND FORAMINIFERA.

ILLUSTRATE with diagrams.

I. Introduction.

As an introduction to this lesson the teacher should explain the meaning of such terms as *Scale of creation, lower tribes, more highly organized beings, more perfect animals,* which are constantly met with in writings about animals. Every animal, however lowly, is perfect in its kind; to take from, or add to, would be to diminish its usefulness in its assigned place in creation, and so when we talk of *more or less perfect* animals, we do not mean more or less perfect in themselves, but in comparison with man. Man we look upon as the type and pattern of animal perfection.

Then as to the word *organized,* an *organ* is a tool, or instrument, designed for some special purpose or purposes, and the word has come to be applied more particularly to the parts of plants and animals serving special purposes; Thus in animals the eye is the organ of sight, the muscles are the organs of movement, the nerves are the organs of feeling, and so on. Now the perfection to which an action is carried must depend very much on the perfection of the organ or tool employed; and the perfection of the tool again depends very much on the number and variety of the functions or duties it has to perform. Thus each of the *hand-feet* of monkeys has to perform similar duties to the hand *and* foot of man, and they are less perfect as hands than our hands, and less perfect as feet than our feet. Two of our organs are set apart specially for locomotion, and two for grasping and handling, and therefore each is more perfect for the work it has to do. Our hands as hands, and our feet as feet, are said to be more highly organized than the hand-

feet of the monkey tribe. Just as with workmen the man who has to do several separate kinds of work is less likely to be perfect in any one than the man who devotes his whole attention to one special work. The more the functions of the body become *specialized*, that is assigned to special organs, and the more perfect the special organs themselves become, the more highly organized is the possessor said to be.

We roughly and very imperfectly arrange the animal creation on the basis of organization, and call it the *Scale of creation.* [It must be borne in mind, however, the brain with its system of nerves is the chief organ on which the arrangement is made to depend.] Every one must feel that the snail is more highly organized than the common earth-worm; for it has not only a larger nervous system, but it has special organs of vision, and of locomotion, which are absent in the earth-worm. In the same way the fish is more highly organized than the snail, a frog than a fish, a bird than a frog, and a monkey than a bird. Man, of course, stands at the top of the scale, immeasurably distant from all.

In this lesson we propose to look at some of the animals at the other end of the scale, the least organized beings; and then in the next lessons those a little in advance, noting as we go along by what gentle steps the student of nature is able to ascend from the contemplation of one form of animal life to another more elevated in the "scale of creation."

II. The Amœba.

A single drop of water drawn from a stagnant pool, an atom of floating weed, or a bit of slime scraped from its surface, placed under the microscope, reveals to us a new world of animal life, organisms different in structure, shape, and general appearance to anything we have seen with the naked eye. Among the many forms we shall, on careful examination, probably find one which consists of nothing

more than a tiny drop of semi-fluid slimy matter, not firm enough to be called jelly, and hardly to be distinguished from the water itself. It has been compared to "a film of ever-changing cloud." This tiny drop, too small to be seen by the naked eye, is an animal, and the simplest or first form of animal life with which we are acquainted. It occupies the lowest place in the "scale of creation."

This simple animal appears to have no special organs, no separate parts or divisions set apart for special purposes like the higher animals. It has neither permanent limbs nor permanent stomach, no mouth, no nerves, no blood tubes, and is quite naked, without even a skin. And yet this singular being has the power to perform all the actions necessary to its life and well-being. It can move from place to place, though slowly enough, either by floating in the water, or by creeping on plants or other objects. It creeps by pushing out portions of its body in any direction, and then drawing the remaining portion of the body after it. The temporary legs take no special form; and, as it moves, the outline of the body is constantly changed. "At one time it is circular, at another angular, and jutting out with capes and peninsulas of no fixed shape, and ever slowly shifting, as if a floating island, restless and bewildered, gained and lost its coasts again and again at the caprice of some changeful sprite, aiming at fancied resemblances to hands, antlers, or branches, and back again to more solid but clumsy shapes of leaves and buds, and even slugs or imperfect stars." It is rightly named *Amœba*, or *change*.

We have said that the Amœba has no mouth and no stomach, and yet it manages to satisfy its hunger. It feeds on creatures smaller than itself, and in lieu of swallowing seems to overwhelm them with its semi-fluid body. It then sucks out the juices, and casts forth the indigestible parts, and is ready when occasion offers to enact the same process over again.

III. Foraminifera.

The marine forms of the Amœba have even stronger claims on our attention than the fresh-water form we have just described. *How* we know not, but they *do*, extract from the ocean flint and limestone, and manufacture for themselves shells of exquisite beauty—shells, not like those of the whelk or snail, but little cases full of tiny holes. Through these holes portions of the body, in the shape of long, soft, glass-like threads, are pushed forth to capture any microscopic prey that comes within reach. The threads assist each other, and when the prey is seized they coalesce and swell, and soon the object becomes enveloped in a thin film. The threads then shorten and the victim is drawn towards the mass or body of the animal. From the structure of the shells the marine forms of the Amœba are called Foraminifera [*Foramen*, a hole, *fero*, I carry]. Exquisite as are the various Foraminiferous shells when seen under the microscope, it is not for their beauty chiefly that we view them with great interest; but for the important part they have taken in past ages, and are still taking, in forming the crust of the globe. They multiply with extraordinary rapidity, and by their numbers make up for lack of size. In many parts of the world the accumulations of these shells form beds covering vast areas and of great thickness, even rising into hills and mountains; and, at the present time, the "mud" forming the bed of the Atlantic in many places consists almost entirely of the shells of Foraminifera.

IV. Sponges.*

Call attention to the structure of the common sponge, and tell the children that this is but the skeleton of what was once a living sponge. The living portion was a glairy substance spread, as a thin coating, over all the fibres of the

* The anatomy and physiology of the sponges are beyond the scope of thees lessons.

skeleton, and which, under the microscope, appears to possess pretty nearly the same characteristics as the soft body of the Amœba. The skeleton is formed by this soft covering, just as the shell of the marine Amœba is formed. It varies in its composition in different kinds of sponges. In some, as in the common sponge, the framework is leathery and elastic; in others the framework is strengthened by glassy spikes of flint or limestone, and sometimes the skeleton consists almost entirely of spikules.

LESSON LXVI.

FIRST FORMS OF ANIMAL LIFE. II.—THE HYDRA.

To be illustrated by diagrams.

I. Introduction.

We pass over a group of microscopic marine animals, the *animalculæ*, viz. *little animals*, to consider a curious fresh-water animal, which in its organization shows a considerable advance on the forms described in the last lesson. It is named *Hydra*. Why so named we shall see presently.

The Hydra lives in ponds and slow streams, and may be found in the summer time hanging from the under surfaces of floating leaves, or attached to the stalks of water-plants. It is obtained for examination by scraping off a little of the slimy surface, or a little bit of the plant itself, and placing it in clear water; or it may be obtained by washing a water-plant in a bottle of water. The water being allowed to stand for a time, the little creatures expand themselves, and may be seen either hanging from the leaves, or attached to the sides of the glass vessel beneath the surface of the water. To the naked eye they appear like green silk threads, about one-sixth of an inch in length and very slender. Under the

magnifying glass it is seen to be fixed at one end by means of a sucker [refer to boys' leather sucker], and to be furnished at the other end with a number of *extremely* fine threads, which float freely in all directions—stretch out, curve, contract, and expand. [See Fig. 7, Appendix.]

II. Structure and Habits.

1. *The Body.*

The minute structure of the Hydra can be seen only under the microscope. The animal has no special organs of sense, although it seems to be influenced by the light. It has no nerves, and consequently, so far as we can tell, no feeling. It is, however, one step removed from the Amœba, for it possesses a body cavity representing the stomach, and an opening into it, which may be called the mouth. The animal in fact may be looked upon as a long, fine tube, with walls of transparent jelly, one end being fringed with tentacles and the other closed by the foot-sucker. The tentacles themselves are tiny tubes opening into the general cavity of the body. They have small holes at their tips.

2. *The Tentacles.*

These tentacles have for their function the capture of prey. Should any minute animal come in contact with either one, its progress is instantly arrested, and the tentacle adheres to it. The others then come to its assistance, and between them the struggling prey is dragged to the mouth, which opens to receive the sapid morsel.

It was long a matter for surprise how these tiny animals managed to seize and retain their prey. This is now readily explained. Under a powerful microscope the tentacles are seen to be set all over with tiny oval sacs, in each of which is coiled up a long delicate filament or thread. These filaments have been compared to the lasso used for capturing cattle and wild horses in South America, and the cells have consequently been not inaptly termed *lasso-cells*.

The Hydra has the power of suddenly flinging out these threads, and woe betide the microscopic unit that comes within their reach. It is entangled in the folds of the cord, like a fly in a spider's web, and is speedily paralyzed. An animal once seized by the Hydra, even if it escapes from its clutches, soon dies; and from this fact it has been inferred that the lasso threads are in some way poisonous in their character.

3. *Digestion of Food.*

The food is received into the body cavity, where it becomes digested. The digested matter is absorbed by the walls, and the undigested portion is thrown out at the mouth.

4. *Locomotion.*

Notwithstanding that the Hydra has no special organs for locomotion it manages to creep about very slowly by means of its sucker. When, however, it is desirous of progressing more quickly, it adopts a method peculiar to itself. It turns a series of summersaults upon its stem. It bends over and fastens itself by its tentacles, then it loosens the sucker, straightens itself and hangs by its tentacles. Now it bends itself over again and fixes its sucker, and then loosens the tentacles and straightens itself. Thus one summersault is complete. [See Fig. 7, Appendix.]

5. *Repairs to the Body.*

Another curious fact in the life of the Hydra is its power of repairing any injury to its body. It may be cut into slices, and each fragment grows into a new animal. It may be slit half way down, and a Hydra with two mouths will be the result. These may be again divided, again and again, and each piece will develop a new mouth surrounded by its tentacles. [Hence the name Hydra, from a fabled monster which, as fast as its heads were cut off, produced new ones.] They may even be turned inside out, like the finger of a glove, and the exterior walls, now the interior, will form a new stomach, and the animal will live and flourish.

6. *Reproduction.*

The ordinary method of increase in the Hydra is by budding. Young animals sprout from the stem of the parent like leaf buds from the branch of a tree. In time these young ones fall off, and take care of themselves; but before the separation takes place, other young ones are in course of growth from these, so that a small colony may be growing on one stem. In the autumn, eggs are developed in the walls, and thrown off. These remain during the winter in the water, and produce young Hydra in the spring.

LESSON LXVII.

FIRST FORMS OF ANIMAL LIFE. III.—SEA-ANEMONES AND CORALS.

ILLUSTRATE with pictures and diagrams, and with specimens of coral. The sea-anemones may be kept for weeks in a glass vessel, provided the water (sea-water) is kept below 60° Fah.

I. Introduction.

Show picture of Anemones. When expanded they resemble beautiful flowers—hence the name. These, together with corals, are called *anthozoa,* a word which means flower-animals. They constitute the flowers of the sea, which, "in the elegance of their forms and brilliancy of their colouring, rival the blossoms that adorn the realms of Flora." Anemones may easily be found on the coasts of England by searching among the rocks at low water. The Red Sea-anemone is very abundant on the south coast. It is a very hardy kind, grows to a moderate size, and will live for years in confinement. When closed it resembles a lump of raw beef. Some of the anemones of the tropics grow to an enormous size.

II. The Sea-Anemone.

1. *Structure.*

We may compare the Red Sea-anemone with the Hydra with regard to structure. Both are soft jelly tubes—the former broad and short, the latter long and thin. Both fix themselves by means of feet-suckers, and both have tentacles round the mouth. The tentacles of both are covered with lasso-cells containing threads used in the capture of prey. Both eject undigested food through the mouth, and both repair injuries in the same remarkable manner as described in the last lesson. And, lastly, neither can boast of organs of sense, nerves, and blood-vessels. Here the resemblance ceases. The anemone is far more sensitive than the hydra. The slightest touch, the shadow of the hand, or even of a passing cloud, will cause the tentacles to shrink and the animal to shut itself up.

The internal structure of the anemone, too, is more complicated—in other words, the animal is more highly organized than the hydra. It shows another step in advance in the "scale of creation." The stomach of the anemone is a bag suspended, as it were, from the mouth. It hangs freely in the centre of the tube, leaving a considerable space between itself and the firm outer wall, and a considerable cavity below, into which it opens. [May be illustrated by suspending a jelly-bag from the mouth of a tall vessel.] The space between the stomach and the outer walls is divided by vertical membranous partitions, which in the horizontal section look like the spokes of a wheel radiating from the box. These compartments are again partially divided by longitudinal folds of the walls, which, however, do not reach so far as the stomach walls. The tentacles open into the spaces divided off by the vertical partitions.

2. *Habits.*

The food is captured by the tentacles, and dragged to the mouth. The digested food appears to pass through the walls

of the stomach into the body, circulating through all the partition walls, and passing thence into the tentacles. The animal can exist without food for a considerable time; but when opportunity offers it is very voracious. Eggs are produced in clusters on the membranous partitions near the walls of the stomach. When developed they fall into the cavity below, and are discharged into the sea through the stomach and mouth.

The contrast between the anemone in repose and in action is very marked. In repose the tentacles are retracted and covered in by a fold of the upper part of the body, so that the animal appears a rounded lump of fleshy substance firmly fastened to the rock. A wrinkled depression on the upper surface is the only indication of any opening into the mass. But when in clear water, under the influence of the sun's rays, the animal becomes full of life and energy, and expands its delicate tentacles like the petals of a beautiful flower; we understand at once why these forms have been called the "flowers of the sea."

Though the sea-anemones appear to us to be fixed to one spot, they possess some power of locomotion. Like the hydra, they can glide slowly over the rock by means of the foot-sucker; and many can detach themselves, and float through the water, till a new resting-place is found. It is said that some kinds occasionally invert themselves and walk on their tentacles. So firmly, however, do these animals attach themselves to the rocks on which they live, that, on removal, fragments of the edge of the base are often left behind, as though it were easier to rend its own tissues than to separate itself from the rock. And so extraordinary are its powers of repairing injuries that the fragments left behind, in a week or two grow into perfect animals. Like the hydra, the sea-anemone seems to defy the effects of mutilation. It may be cut in two, and each part will immediately develop the missing part and form a new animal.

III. Corals.

The so-called "coral insects" are little polypes,* similar in structure to the sea-anemones. Indeed, in the young state they are almost identical; but as growth proceeds limestone is deposited within the fleshy substance, so that the walls and foot-sucker and the partition walls become solid, the only soft portions left being the stomach, the mouth, the tentacles, and the fleshy skin covering the solid walls. [We may say that the anemone bears a similar relation to the coral that the Amœba bears to the Foraminifera.] The skeletons thus formed become solid cells for the lodgment of the polypes, and into which they can withdraw, just as the sea-anemone retires within itself.

Such are *simple* corals; but some, especially the reef-builders, are compound, that is, they increase by buds, like the hydra. A little knot appears in the fleshy covering; this develops into a soft polype, which quickly secretes a stony skeleton. Other buds arise, the buds begin to bud, and in a short space of time one polype has produced millions. Some species grow in a bush-like form, in others limestone is deposited in the interspaces between the buds, connecting the whole into a solid mass.

In one large section of the corals no cells are formed for the lodgment of the polypes. This is the case with the beautiful red coral dredged up from the floor of the Mediterranean, and used for making ornaments. This coral has a solid axis, variously branched, which supports an external living flesh. This outer covering secretes the solid axis, and forms the common base for the support of the polypes.

* Many-footed—referring to the tentacles.

LESSON LXVIII.

PLANT-FACTORIES.

(To Occupy the Time of Two or Three Lessons.)

For illustration: diagrams and pictures, a glass funnel, a piece of soft bladder, a little sugar, and a glass vessel sufficiently large to admit the funnel.

I. The raw Material.

Take any common plant, such as a cabbage or a potato. What is its food, and whence is it derived? Its roots are in the soil, and its stem and branches and leaves are in the air. Hence the food can be obtained only from the soil or the air, or both.

Plants cannot live in a dry soil. Call the attention of the children to the different appearance in the vegetation brought about by rain-showers after a spell of hot dry weather. Water is a prime necessity to the life of a plant. It is taken in mainly by the roots; but some moisture is absorbed by the leaves, either from drops of rain, or dew, or from the vapour of water in the air. [Show, by putting a plant in a vessel of water, how the liquid is absorbed by the roots.] Water then is the first food of the plant.

Burn any portion of a plant, and some earthy matter is left behind in the shape of ashes. Whence was this matter derived? Water while soaking through the soil dissolves very minute quantities of the mineral matters contained therein; and these are carried into the plant through the medium of the water absorbed by the roots. A small amount of a volatile gas, called ammonia, is also carried into the plant in the water imbibed. Traces of ammonia are found in the air, and some of this is probably carried down to the soil by the rain; but the greater portion is derived from manure, and decaying animal and vegetable matter generally.

The teacher may turn aside for a moment here to point out the curious and interesting fact that the roots of plants have a power of selection when taking food from the soil. They select such matters as are necessary to their proper growth and development and reject all others. On this and the fact that all plants do not select the same matters the farmer founds his "Rotation of Crops."

Partially burn or char a piece of wood, and charcoal, or carbon is left behind. Whence did the plant obtain this material? Clearly not from the soil, for carbon is not soluble in water, and the tiny rootlets cannot take in solid matter. Carbon then must be obtained from the air. It is supplied in abundance by the carbonic acid gas always present, and is taken in through the millions of little breathing pores found in every leaf. Carbonic acid gas is made up of carbon and oxygen. The carbon is retained and *fixed* by the plant, and the oxygen is set free.

The raw materials then on which plants work are air, moisture, and the earthy and other matters which the rain-water dissolves as it percolates through the soil.

II. The Factory.

The leaf is the factory. For minute structure and general description see Chapters VI. and VII.

III. Carriage of Raw Materials.

The crude sap, viz., the water in which very minute quantities of earthy and other matters are held in solution, is imbibed by the rootlets. Now the leaves are the factories in which the extraordinary transformations occur, by which *inorganic* materials are changed into *organic;* hence the crude sap must be carried to the leaves. There is no set of tubes or pipes set apart for its special conveyance. The roots, stems, branches, and leaf-stalks, as well as the leaves themselves, are all built up of cells and vessels with complete

membranous walls, and through these walls all the juices of the plant have to pass. *How* they pass so readily is not very well understood: that they *do* pass is perfectly certain. If the stem of a vine be cut through, when the sap is ascending; and a piece of bladder be tied over the lower part, this soon becomes distended with liquid, and in a few hours the bladder will burst. Call attention to the decrease in a volume of water in a vessel in which plants or cut-flowers have been placed. To rise an inch the sap has to pass through several hundreds of the cell-walls. In the stem it ascends mostly through the elongated vessels of the woody tissue. If the bark and outer layer of wood be removed from a growing stem a large quantity of liquid will flow out.

It must not be supposed that the crude sap as it reaches the leaves is in a condition precisely the same as when imbibed by the roots. In its passage it necessarily mixes with the matter stored up from the previous year, or already manufactured in the present year; and in proportion as it ascends it absorbs more and more of this, so as gradually to take on, to some slight extent, the special characters of the plant itself.

IV. The Manufacture.

Distributed through the millions upon millions of cells in the broad expanse of the leaves, the crude sap is exposed to the influence of the light, and brought into contact with the air, which is taken in through the little breathing pores. Much of the water of the crude sap which was necessary for the conveyance of the minute portion of earthy matter, &c., from the soil, is now no longer necessary and is sent off in the form of vapour through the breathing pores. This may be shown by placing a small growing plant under a bell-jar in the sunshine. The moisture will be seen condensed in the sides of the glass.

The thickened crude sap which remains undergoes, under

the influence of the light, a remarkable change, the nature of which is to us a mystery. The *mineral* matter becomes *vegetable*. The materials derived from earth, air, and water become transformed into a thin mucilage—a substance precisely similar in all respects to the plant itself. This is *digested* or *elaborated* sap, and is to the plant what prepared clay is to the vessels which are to be formed from it. This newly made vegetable matter is ready to be carried to any part of the plant, where it is wanted for the purpose of growth, or to be stored up for future use. It descends chiefly through the inner bark, at least in trees and shrubs; but in herbs through the soft parts generally, and the necessary portion finds its way to the rootlets themselves. Some part is also diffused laterally throughout the stem, and there, of course, it meets with the crude sap. It is plain therefore that, although most of the crude sap ascends in the woody tissue of the stem, and most of the prepared sap descends through the inner bark, there is no separate circulation of the two kinds of sap; neither can crude sap nor prepared sap exist separately in any part of the plant.

The process by which the crude and elaborated saps pass and repass may be easily illustrated but not explained. Take a glass funnel with a long stem, cover the wide mouth with a piece of soft bladder, and fill the open part with thick syrup. Then partially immerse the funnel in a vessel of water. The syrup represents the elaborated sap and the water the crude sap. After a short time the volume of liquid in the funnel will be seen to be much increased, and on testing the water in the glass, it will be found to be sweet to the taste—the water has found its way through the bladder into the funnel, and some portion of the syrup has passed out into the water. If the position of the liquids be reversed, the water in the funnel will decrease in volume, and the volume of syrup in the vessel will increase.

V. The Products.

The primary product is, of course, the elaborated sap. This we may call *plant-food*, as it is by means of this material that all new growth in a plant is made. A large proportion of this food is used as fast as it is made; but a considerable portion is stored up in various parts of the plant for future use. In annual herbs, for instance, nearly all is used for the purpose of growth, flowering, or seeding as fast as produced. In biennials, such as the turnip and carrot, a large portion is stored up in the root for use next year. In the potato plant it is laid up in the tuber. In shrubs and trees a part is deposited each season in the new wood and bark, to be used in developing the buds in the following season. In all seeds, and seed-like fruits, a store is provided for the seedling, or new plant.

The plant-food may be stored up in the shape of thin mucilage (or gum), starch, or sugar. These three forms of plant-food are present in all plants, but in varying proportions. Mucilage is always to be found in the new wood and bark of shrubs and trees, and is present in such abundance in the gum trees as to flow in plenty from the wounded bark. Starch is specially abundant in the various cereals, in the tubers of the potato, in the root of the arrow-root plant, and in the pith of the sago plant. Sugar abounds in the sugar cane, the sugar maple, and in beet-root, and carrots. These substances—mucilage, starch, and sugar—are almost, if not quite, identical in chemical composition, and the plant readily changes one into another according to its needs. In the wheat plant, for example, a portion of the plant-food is changed into starch, and stored in the seed grains. Under the influence of air, warmth, and moisture in the soil, the starch of the seed changes to sugar, and the sugar to plant-food for the growth of the young seedlings. (Flour made from corn which has sprouted makes sweet bread.)

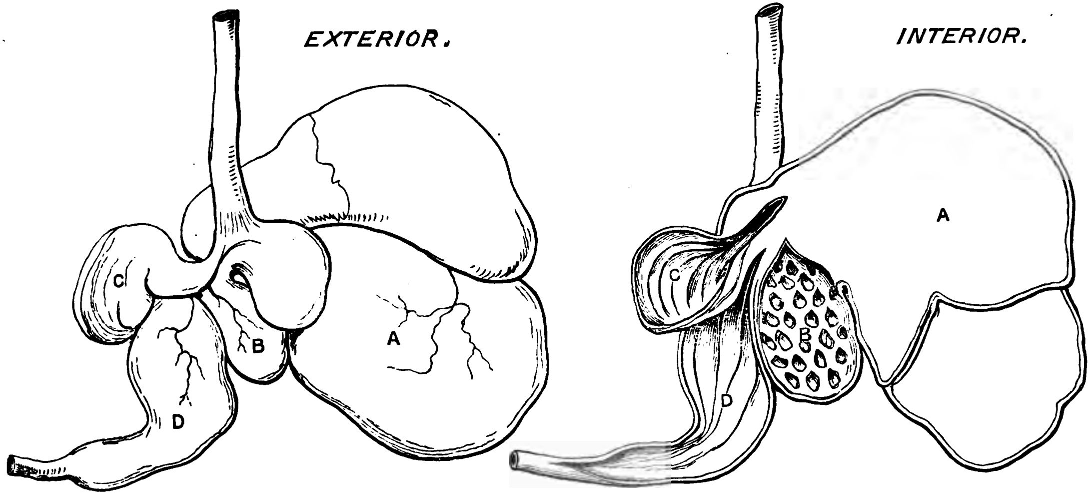
As these substances are concerned specially in the nutrition of the plant we may call them *Nutritive Products.*

In addition to the Nutritive Products there are very many others, of which different kinds are found in different plants, but which, so far as we know, take no part in the formation of the tissues of the plant. They usually appear in the elaborated sap ; but often become separated from it and stored up in some particular part of the plant. All the most important of these *Special Secretions,* such as tannin, india-rubber, gluten, gutta-percha, the various oils, resins, camphor, opium, &c., &c., have been dealt with under the head of "Economic Products of Plants."

APPENDIX.

SPECIMEN OUTLINE DRAWINGS FOR THE BLACKBOARD.

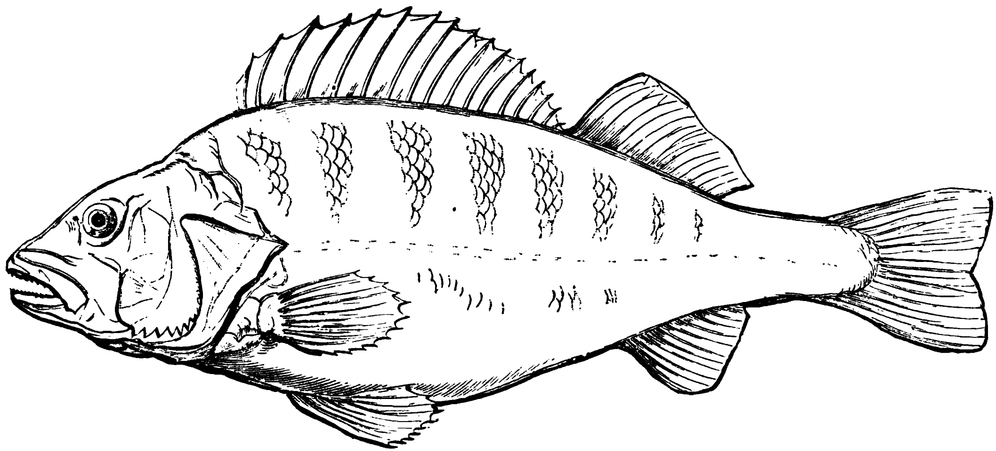
No 1.



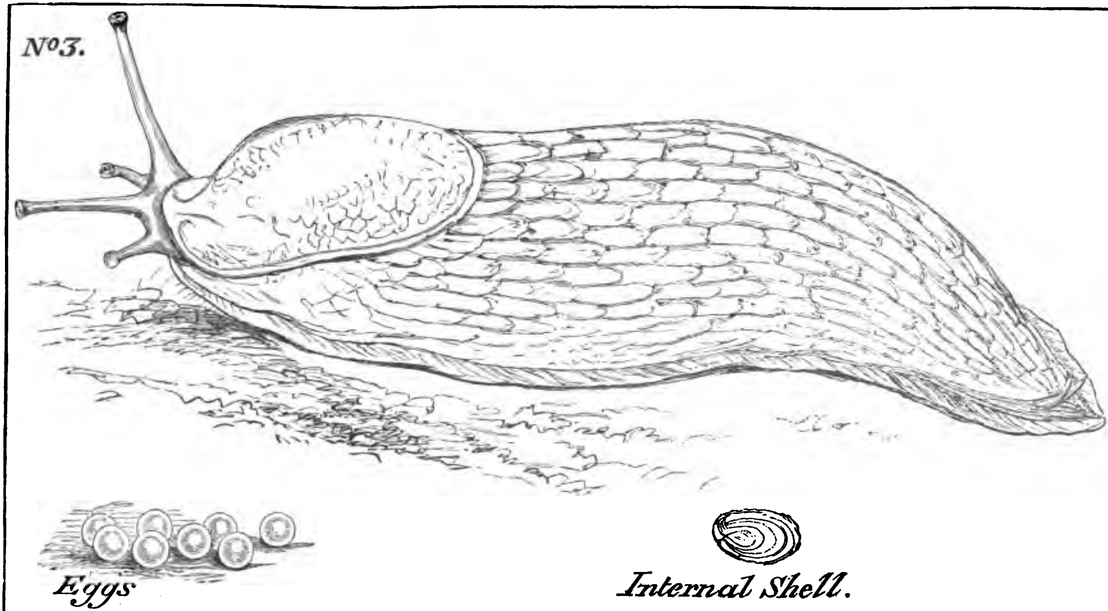
A.A. *Paunch.* C.C. *Maniplies.*
B.B. *Honey-comb.* D.D. *True Stomach.*

STOMACH OF COW.

No. 2.

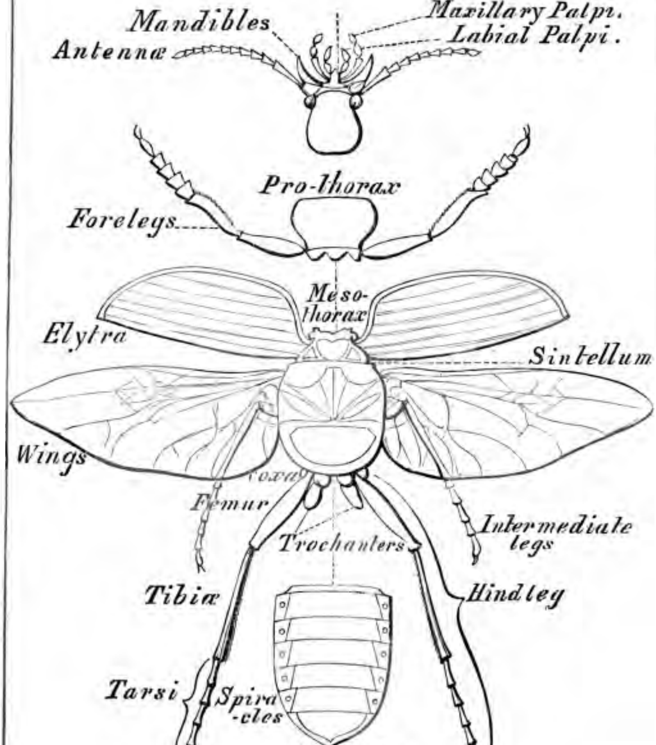


PERCH.

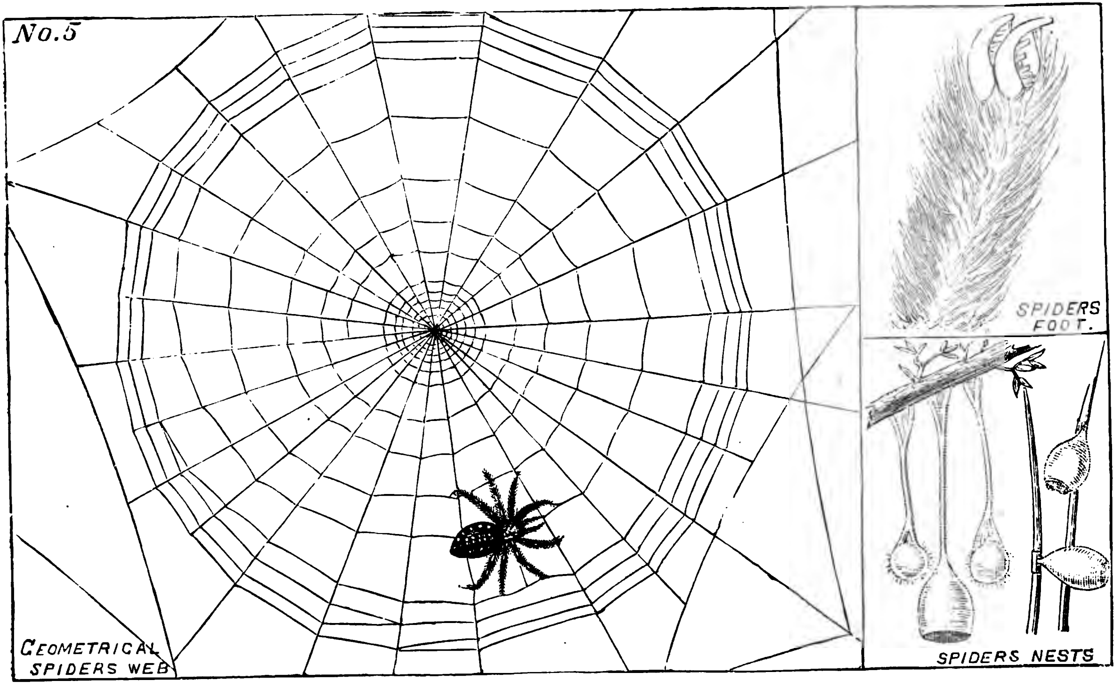


SLUG

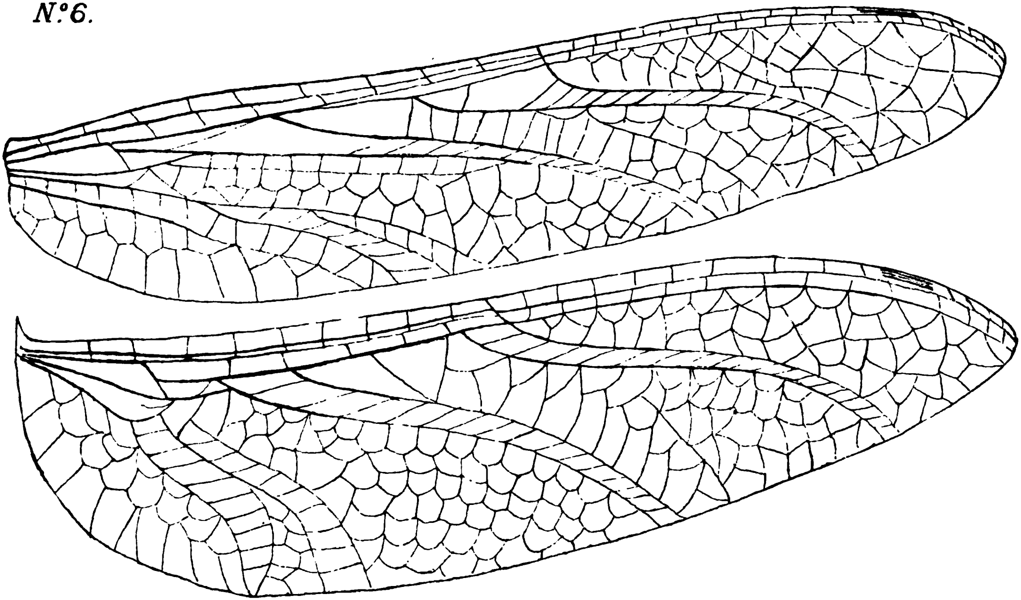
No. 4.



Insect shewing parts.

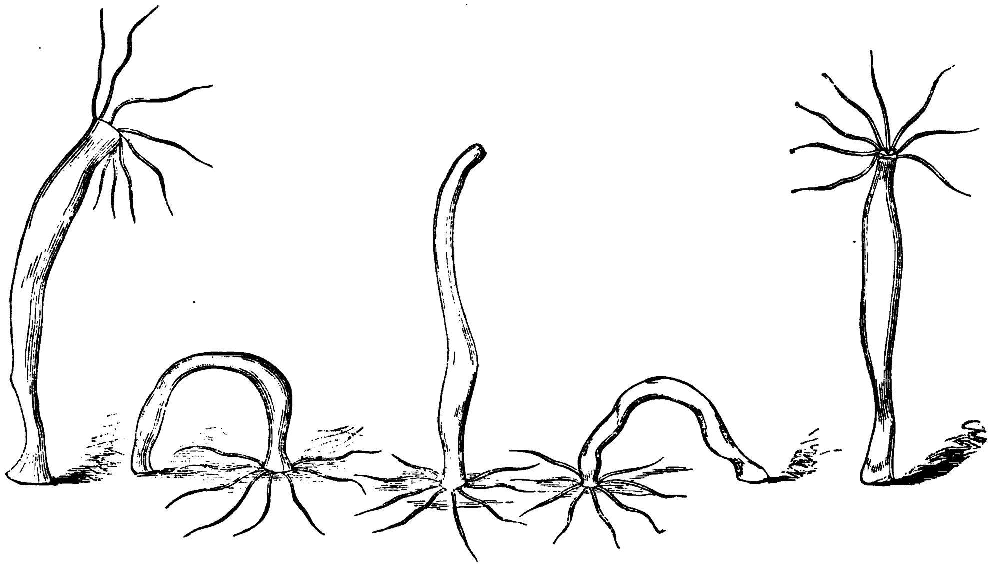

No. 5
GEOMETRICAL SPIDERS WEB
SPIDERS FOOT.
SPIDERS NESTS

N.º 6.



Wings of Dragon-Fly.

No. 7.



Hydra turning Summersaults.

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